Environment Agency

Regional Beach Management Plan 2017:
Littlehampton to Brighton Marina

Report – ENVIMSE100035/R-01

Final Report, July 2017

This series of regional Beach Management Plans for Southeast England are dedicated to the memory of Andy Bradbury.

The data that has been used to compile them is only available due to Andy's vision and drive for better coastal monitoring data to inform beach management.

Regional Beach Management Plan 2017

Littlehampton to Brighton Marina

Main Report

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EXECUTIVE SUMMARY

This Beach Management Plan (BMP) has been prepared by **Canterbury City Council** on behalf of **Arun District Council, Adur and Worthing Borough Council, Brighton and Hove City Council, Shoreham Port Authority and the Environment Agency**. The BMP sets out the implementation approaches for intervention and monitoring to maintain the beach where it provides an integral part of the sea defences between Littlehampton and Brighton Marina. The aim of the BMP is to inform, guide and assist these responsible authorities and organisations in managing the beach, and to ensure that the beach management continues to manage the risk of coastal flooding and erosion.

Beach Management Plans provide an accountable and transparent methodology for managing beaches as coastal defence assets based on risk information that derives from scheme design, monitoring and scientific/research input with the aim of managing the frontage in a sustainable way that enhances vegetated shingle habitats.

To this effect the BMP contains the evidence base that has led to the management options. To achieve this aim of accountability and transparency, all source data, documents and methods are appended to this report in the Appendices and in digital form in the enclosed DVD.

The BMP proposes the following activities:

- Continued monitoring as part of the Regional Coastal Monitoring Programme.
- Annual bypassing at 13,700 m^3 from Shoreham Harbour Arm to Southwick Defence Sections C and D, with the aim to recycle 15,000m^3 annually.
- In the longer term, consideration could be given to restricting recycling activities to within each sediment cell, Littlehampton to Shoreham Harbour and Shoreham Harbour to Brighton Marina.

1 INTRODUCTION

1-1 PRESENT SITUATION

1-1-1 SMP AND OTHER STRATEGY POLICY

The coastline between Littlehampton and Brighton Marina falls within the coastal frontage of the Beachy Head to Selsey Bill Shoreline Management Plan (2006) including policy units 4d18 (Angmering-on-Sea to Littlehampton) to 4d12 (Brighton Marina to Portslade-by-Sea), Table 1-1. The frontage is managed under the responsibility of several organisations, shown in Figure 1-1 overleaf.

The Rivers Arun to Adur Flood and Erosion Management Strategy (2011) extends between the River Adur to Littlehampton and the Brighton Strategy Appraisal Report (2014) covers the coast between Brighton Marina to the River Adur.

TABLE 1-1 SMP POLICIES WITHIN BMP

POLICY UNIT	DESCRIPTION	SEDIMENT TYPE	SHORT TERM	MEDIUM TERM	LONG TERM
4D17	ANGMERING-ON-SEA TO LITTLEHAMPTON	SHINGLE	HTL	HTL	HTL
4D18	FERRING/KINGSTON	SHINGLE	HTL	HTL	HTL
4D16	WORTHING TO GORING-BY-SEA	SHINGLE	HTL	HTL	HTL
4D15	SHOREHAM HARBOUR TO WORTHING	SHINGLE	HTL	HTL	HTL
4D14	RIVER ADUR	SHINGLE	HTL	HTL	HTL
4D13	SHOREHAM HARBOUR (SOUTHWICK)	SHINGLE	HTL	HTL	HTL
4D12	BRIGHTON MARINA TO PORTSLADE-BY-SEA	SHINGLE	HTL	HTL	HTL

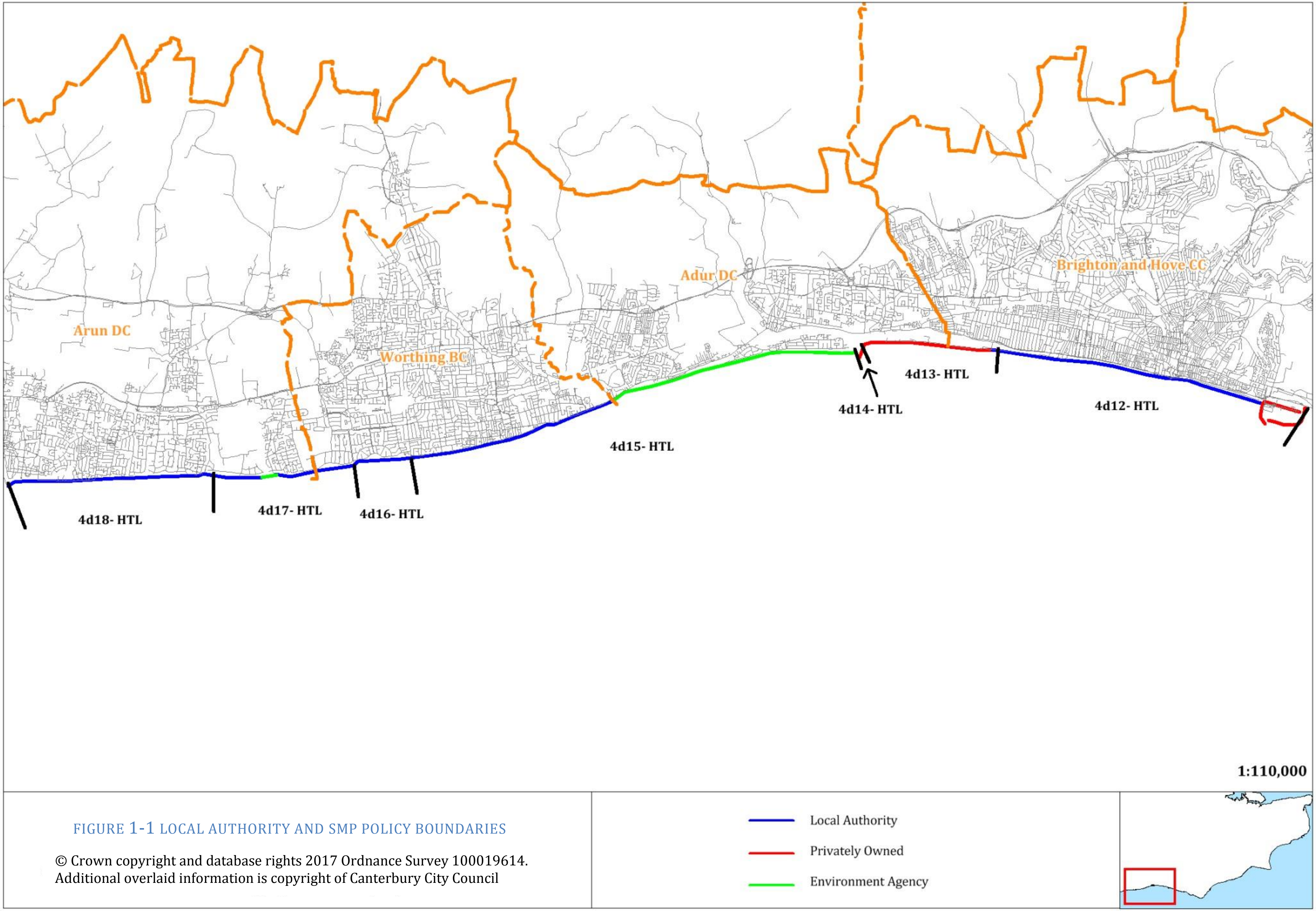

FIGURE 1-1 LOCAL AUTHORITY AND SMP POLICY BOUNDARIES

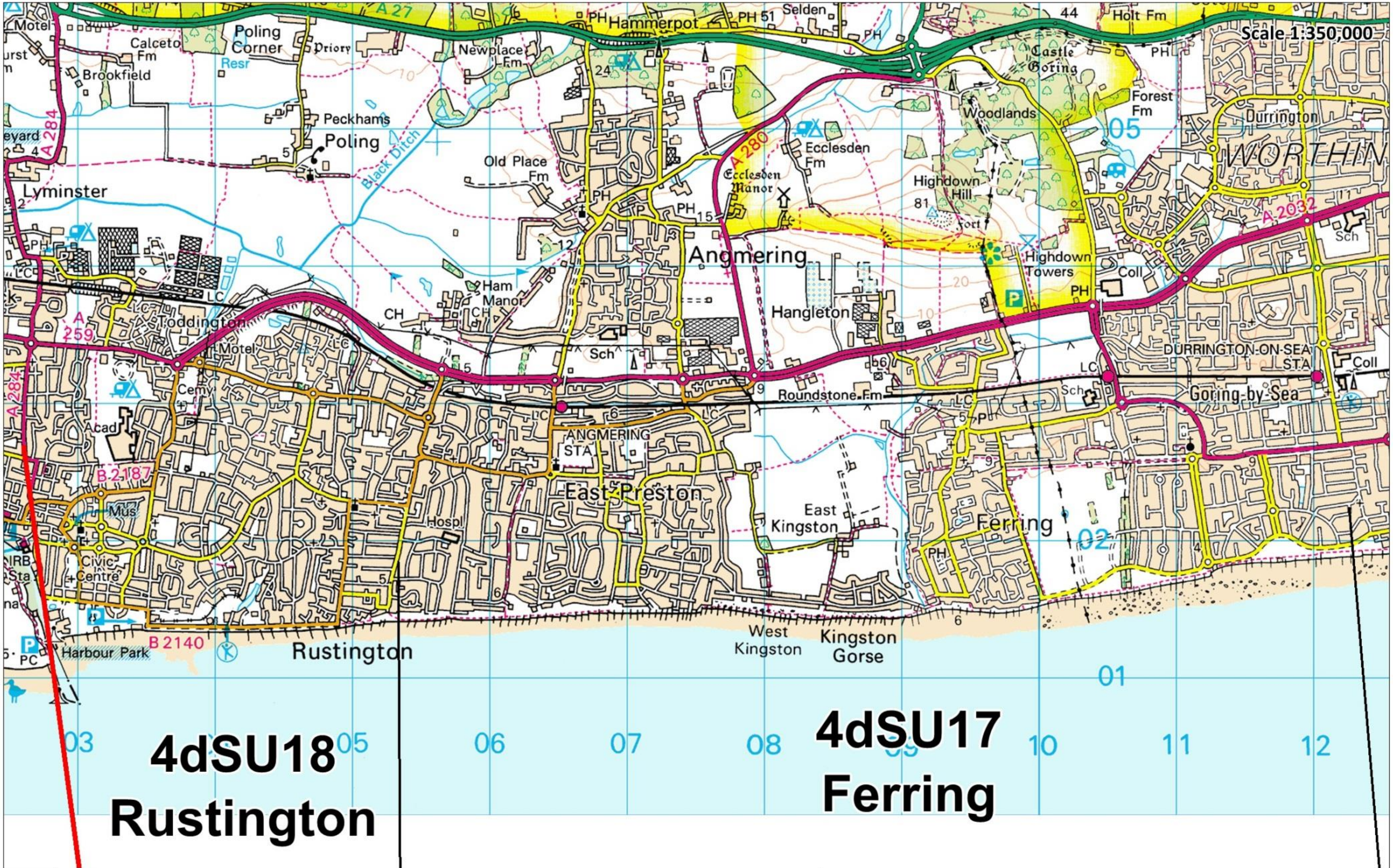

FIGURE 1-2 UNIT BOUNDARIES – RUSTINGTON AND FERRING

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RCMP Unit Boundary

CANTERBURY CITY COUNCIL

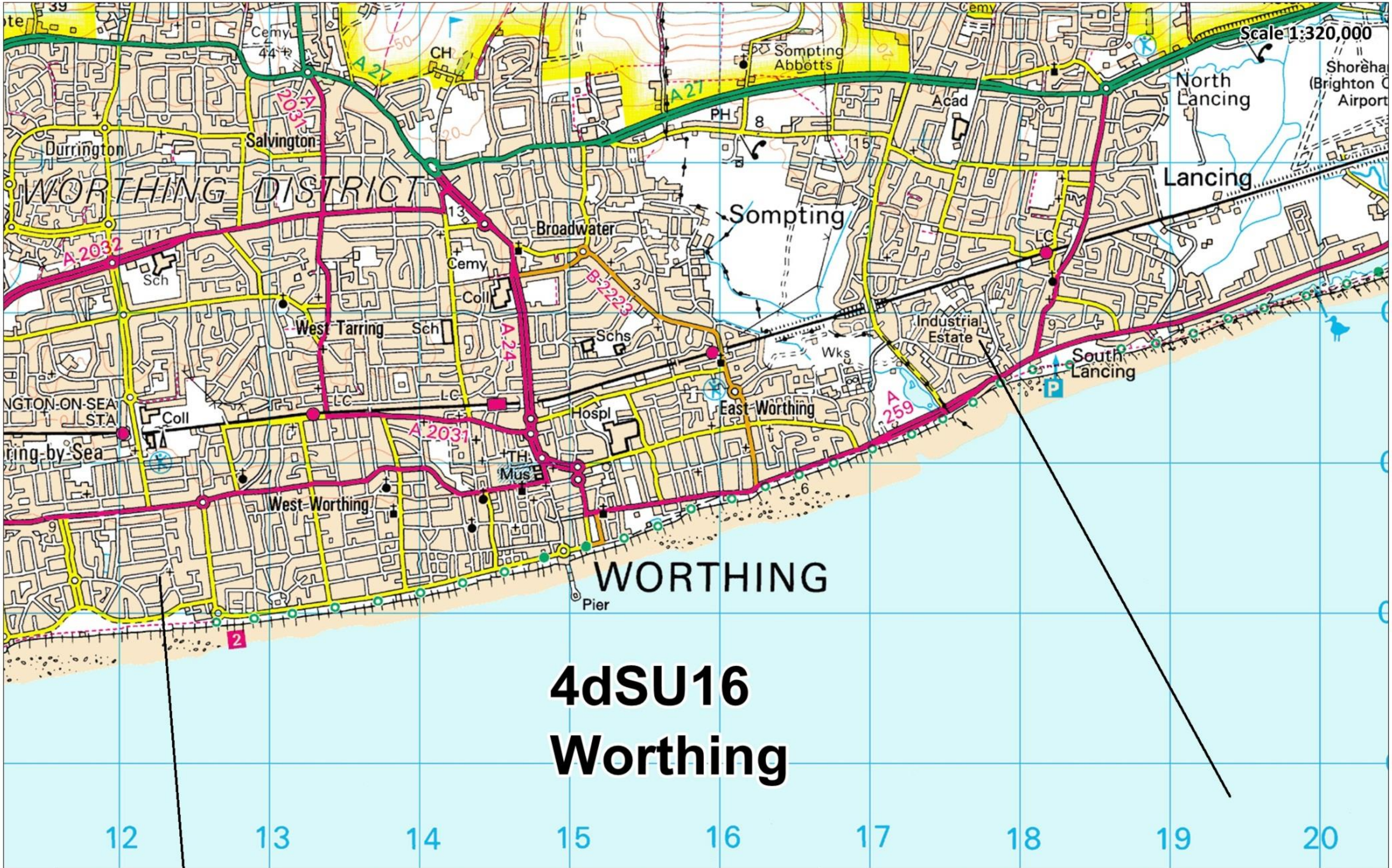

FIGURE 1-3 UNIT BOUNDARIES – WORTHING

RCMP Unit Boundary

CANTERBURY CITY COUNCIL

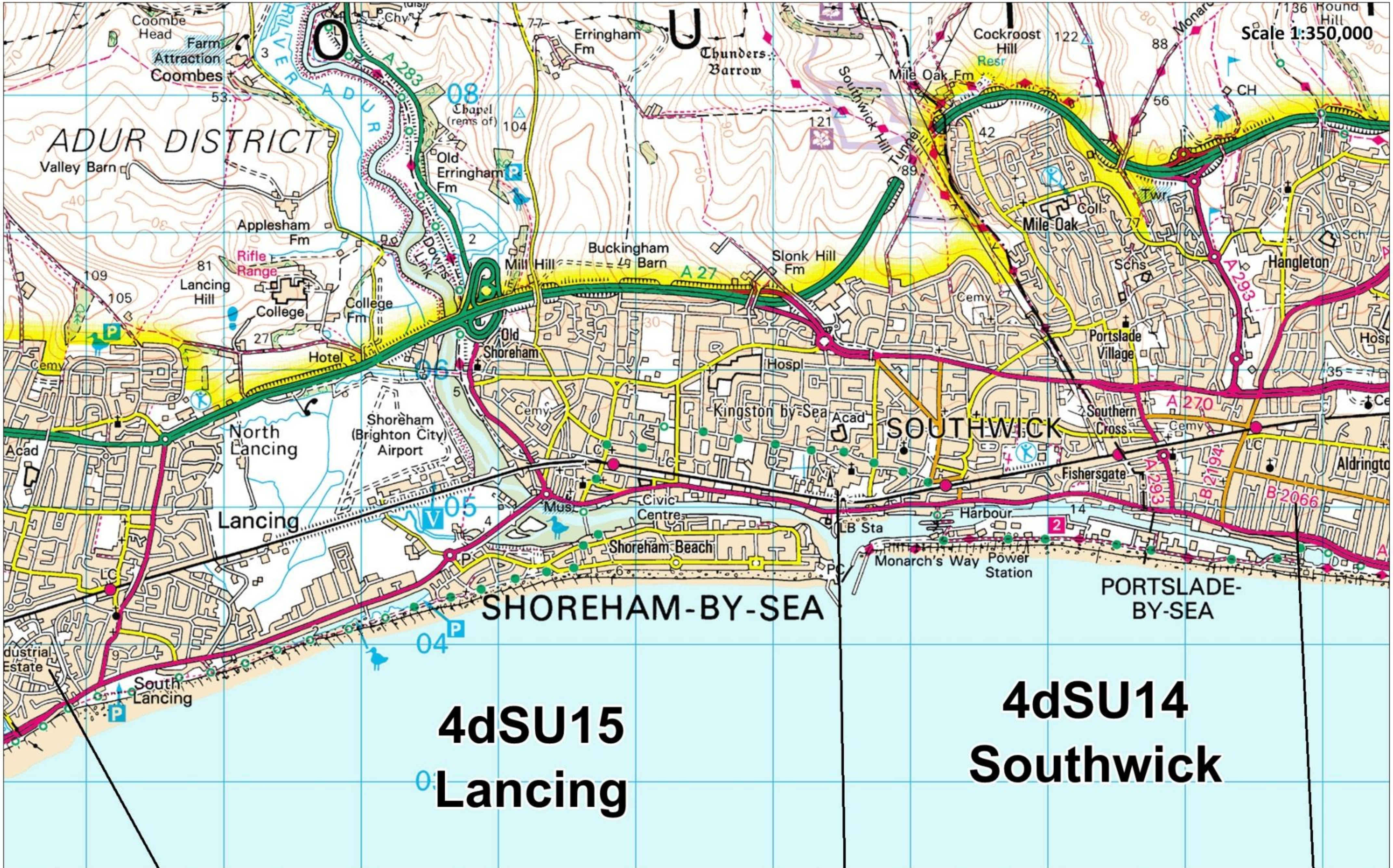

FIGURE 1-4 UNIT BOUNDARIES – LANCING AND SOUTHWICK

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RCMP Unit Boundary

CANTERBURY CITY COUNCIL

FIGURE 1-5 UNIT BOUNDARIES – BRIGHTON AND HOVE

RCMP Unit Boundary

1-1-2 PHYSICAL CHARACTERISTICS AND COASTAL DEFENCES

The section of coastline between Littlehampton and Brighton consists of mainly low lying land, with chalk cliffs at Brighton Marina. A well-defined gravel beach and a low gradient sandy foreshore dominate this section of coastline. The River Arun marks the most westward boundary at Littlehampton with Brighton Marina at the most eastern boundary. The mouth of the river Adur flows into Shoreham Harbour.

Refer to Appendix A - Oblique Aerial Photography for place names and frontage overview.

LITTLEHAMPTON TO RUSTINGTON

The frontage between Littlehampton Harbour and Rustington is 2.5km long and extends from Littlehampton harbour in the West to Broadmark Road in the East. The main road (Sea Road-B2140) runs parallel to the coast for the majority of the frontage with both residential and commercial properties in close proximity to the beach (Arun to Adur Strategy, 2011). At the eastern end of this section the main road turns inland and the residential area becomes a private estate. The beach consists of a mixed sand and shingle beach with a slope of 1 in 7 to 1 in 10, which flattens towards the beach toe

The defences protect the village of Rustington and consist of a concrete vertical wall (+4.9-5.2 mOD) extending from the harbour to Littlehampton Skate Park. A concrete recurve wall at +5.8 mOD extends for 275m. A timber vertical wall at an elevation of +6.3 mOD extends from opposite Marama Gardens to the beach shelter at the end of Sea Road. A concrete promenade extends for the majority of the frontage, extending from the harbour to in front of the RAF Nursing Home just west of Broadmark Lane.

FIGURE 1-6 ROCK GROYNE TO THE SOUTH OF SEA ROAD

There are two outfalls within this section (Mott MacDonald, 2015); one supported by a concrete structure (Hendon Avenue), and a timber frame supported by piles (Broadmark Lane). There are 30 timber groynes along the entirety of this unit with the majority spaced 50-70 m apart (Mott MacDonald, 2015). An open shingle bank interrupts this groyne field between East Beach Café and the Littlehampton Swimming and Sports Centre. A rock groyne is located to the south of Sea Road but it is not acting as a terminal structure (Figure 1-6).

RUSTINGTON TO FERRING

Rustington to Ferring extends between Broadmark Lane in the west to Worthing Yacht club in the east and is 7 km in length. There are a large number of private estates in the area; limiting access to the beach to public footpaths. The urban areas of Ferring are immediately behind a low vegetated bank at the back of the beach (Arun to Adur Strategy, 2011). The beach is predominantly mixed shingle sand with varying crest width of 20 to 40 m at +5.8 mOD with a slope of 1 in 7 to 1 in 10, which flattens towards the beach toe

There are two short sections of hard defence at Ferring; a 200 m timber wall at +5.7 mOD fronting the Blue Bird Café, (Figure 1-7) and a short concrete wall (+6.7 mOD) and promenade that extends for 80 m behind Arundel Court. A total of 135 timber groynes and 10 rock groynes hold sediment along Ferring (Mott MacDonald 2016a). The spacing and orientation vary across the whole frontage. Responsibility of these groynes is shared between Arun DC, Adur & Worthing BC and the Environment Agency (Mott MacDonald, 2016a). Nine outfalls are present, with the majority consisting of concrete casing or a timber frame with supporting piles.

FIGURE 1-7 TIMBER BREASTWORK IN FRONT OF THE BLUE BIRD CAFÉ, FERRING

WORTHING

Worthing is the 6km stretch of coast between the Yacht Club and Lancing Beach Green. The large, densely populated town of Worthing is at risk of flooding and overtopping due to the close proximity of both residential and commercial properties to the beach with the main road, A259, running parallel to the beach for the whole frontage (Arun to Adur Strategy, 2011). The beach is mixed shingle sand at +5.7 mOD and a crest varying between 22 m and 40 m with a slope of 1 in 7 to 1 in 10, which flattens towards the beach toe.

There is a variety of coastal defences, moving west to east; the Yacht club to the Pier is defended by a large timber groyne field backed by an intermittent concrete splash wall at between +5.3-6.5 mOD.

FIGURE 1-8 SPLASH POINT, WORTHING

Between West parade and Splash Point, there is an intermittent wall at (+5.5- +6.6 mOD) with several access points that run along the promenade. Splash Point is a vertical sea wall (+6 mOD) protected by a rock revetment, this was constructed in the 1990s. Splash Point to Ham road has a concrete promenade that is protected at each end with a rock revetment and sea wall at varying heights (+5.5 mOD to +6.3 mOD). Beyond Ham Road the majority of the frontage is protected by a groyned beach, with intermittent splash walls in places.

The timber groyne field is not uniform in length or spacing. There are 107 timber groynes owned and maintained by Worthing BC and a further 12 maintained by the Environment Agency (Mott MacDonald, 2016b). A total of 11 outfalls are spaced along this frontage and are predominantly encased in concrete or supported by a timber construction. There are nine rock groynes at the Eastern extent by the boundary with Lancing unit.

LANCING

The beach at Lancing extends 5.6 km from Lancing Beach Green in the west to Shoreham Harbour in the east. The coastal defences protect a large floodplain and residential area. The shingle spit that forms the beach at Lancing has a complex history of movement (Robinson and Williams, 1983). It is characterised by a shingle storm ridge with a slope of 1 in 7 to 1 in 10, which flattens towards the beach toe. The beach material comprises shingle and sand with a sand foreshore.

There are a variety of defences at Lancing, the first of which is a timber wall, stretching from Lancing Beach Green to the middle of Widewater lagoon (Figure 1-9). This timber wall is built at a level of +5.5 mOD between the Beach Green and the sailing club, where is increases in height to +6.7 mOD. There is a short section of recurved concrete sea wall fronting the Widewater Lagoon at a level of+5.6 mOD. Prior to the construction of this sea wall, there was a 600 m breach of the barrier beach in 1908.

FIGURE 1-9 LANCING ROCK GROYNES AND WIDE WATER LAGOON

There is a small rear wall at +6.5 mOD that extends from the west of King's Walk to opposite Weald Dyke. The rest of the coastline to Shoreham Harbour is largely undefended. The harbour arm in the east acts as a terminal structure and allows sediment to accrete on the western side of this structure. The harbour arm itself is built to +5.5 mOD and a concrete sea wall backs a small beach between the harbour arm and estuarine retaining wall.

There are 33 rock groynes along the beach at Lancing which are approximately 60-70m long and at 100m intervals. 160,000 tonnes of Norwegian granite and French Limestone was imported for their construction in 2006.

Provisions of Clause 49 of the Shoreham Harbour Act 1949 apply additional legislation to Shoreham Port. These provisions allow the Trustees (now Shoreham Port Authority) to remove shingle from the beach to the west of the harbour entrance and deposit it on harbour land to the east of the harbour entrance, subject, in effect, to the approval of the local Coast Protection Authorities.

The Act was written to enable the construction of the (then) proposed new harbour arms, lock and coast protection etc. to go with the (then) new power station proposed by the British Electricity Authority. The 'Authority' referred to in the Act is the British Electricity Authority and not Shoreham Port Authority, which did not replace the Harbour Trustees until 1976.

SOUTHWICK

The frontage at Southwick consists of two different beaches, Kingston beach and Southwick beach, Kingston Beach is physically separate to Southwick beach. Inclusive of both beaches this frontage stretches from Shoreham harbour in the west to Hove lagoon in the east (3.7k m).

Kingston beach lies sheltered inside the harbour. It is characterised by a shingle and sand beach with a mud sand foreshore. The beach is backed by a retaining wall and a clay embankment, which protects the main road and residential areas behind. In the middle of the beach around the MHWS spring position is a timber breastwork that was substantially repaired in 2014/15. There are 6 timber groynes in total.

Southwick beach extends from Shoreham Harbour arm to the Hove lagoon. The beach consists of shingle and sand with a sand foreshore, and has a slope gradient of 1 in 9. Within the harbour arm beach there is a rock revetment which is built to a level of +4.5 mOD with a slope of approximately 1 in 7 to 1 in 10, which flattens towards the beach toe, although steeper in parts with a slope of 1 in 5.5. To the east of the harbour arm there are two rock groynes 250 m apart. The sea wall is made of concrete sea bees, designed to help dissipate wave energy (Figure 1-10).

FIGURE 1-10 SEABEES ALONGSIDE SHINGLE BEACH AND ROCK GROYNE, EAST OF HARBOUR ENTRANCE, SOUTHWICK

Since construction of the harbour arm in 1880, there have been severe scour problems along the Shoreham East frontage. In response to this there are a variety of hard defences ranging from rock revetments, Seabees and several controlling structures, including both rock and timber groynes.

A vertical concrete sea wall, built to +7.0 mOD, 10 wooden and 2 rock groynes stretch 700 m from the harbour gates eastwards. The eastern extent of this section is marked by an outfall. Between the rock groynes and the rock revetment at the easternmost extent of the unit there is a series of dilapidated defences, including corroded sheet piled wall, wooden crib walls and a large concrete wall.

BRIGHTON AND HOVE

Brighton stretches from Hove Lagoon in the west to Brighton Marina and is 6.8km in length. Brighton is a densely populated tourist resort with a high number of amenities. The western end has a risk of overtopping whilst the eastern half the beach is backed by high rising ground. The beach is shingle and sand with a sand foreshore with a 1 in 7 to 1 in 10 slope, which flattens towards the beach toe.

Starting in the west, at Hove, there is a 120m stretch of coast in front of the Lagoon which is undefended. To the east of the Lagoon is vertical sea wall stretches for 200m which changes to a stepped revetment and vertical wall at +6.5mOD which runs east for 300m (Figure 1-11). A series of vertical walls between the tennis courts and Brighton Marina ranging in height from +6.6mOD to +8.0mOD rising from west to east. Between Meeting Place Café and the Brighton Marina there is a high retaining wall which does offer some protection against flooding. Small shops and cafes built into the arches have historically been flooded. There are eight outfalls between the Pier and the marina, two of which act as controlling structures.

FIGURE 1-11- STEPPED REVETMENT, HOVE

1-1-3 GEOLOGY

TOPOGRAPHY

Between Littlehampton and Brighton Marina, the backshore is characterised by a gently sloping hinterland in the west and steeply rising ground and cliffs in the east (Figure 1-12).

BEDROCK & SUPERFICIAL DEPOSITS

The Littlehampton to Rustington, Rustington to Ferring, Worthing and Brighton and Hove units are underlain by Chalk bedrock; a band of clay stretches through the centre of the study area extending from Lancing to Southwick (Figure 1-13).

Fine deposits overlay this, including gravels, sand, silt and clay in the lower parts and Coombe Rock deposits in front of the cliffs (Figure 1-14). Tidal flat deposits can be found within the River Adur flood plain.

COASTAL EVOLUTION

The shoreline between Littlehampton Harbour and Brighton Marina has been shaped by post glacial sea level rise, when the entire English Channel and Dover Straits were inundated around 8,000 years ago. Breaching of the low-lying land that once split this water body from the North Sea, initiated a strong eastward transport of sediment into the eastern channel. During the early stages of this period, the onshore migration of this sediment led to major episodes of sediment accumulation resulting in the formation of shingle barriers. A shingle barrier now extends the length of the coastline, starting at Selsey Bill to Brighton Marina, and, in the majority of places, is a relict feature (Future coast, 2002).

The present day shoreline was formed by the onshore migration of a shingle barrier over the low-gradient coastal plain in response to post-glacial sea level rise. Some shingle remained on the coastal plain and now forms submerged deposits that periodically provide a limited supply of sediment to the shoreline. The growth of spits across the mouths of the River Arun and Adur due to eastward longshore transport resulted in the deflection of the rivers to the east. The shoreline is eroding as evidenced by the loss of villages between Selsey and Lancing to the sea in the past (Future coast, 2002). Within the last few years, one of the banks around Selsey Bill has become attached to the Selsey shoreline, representing a pulse of sediment to the beach (Future coast, 2002).

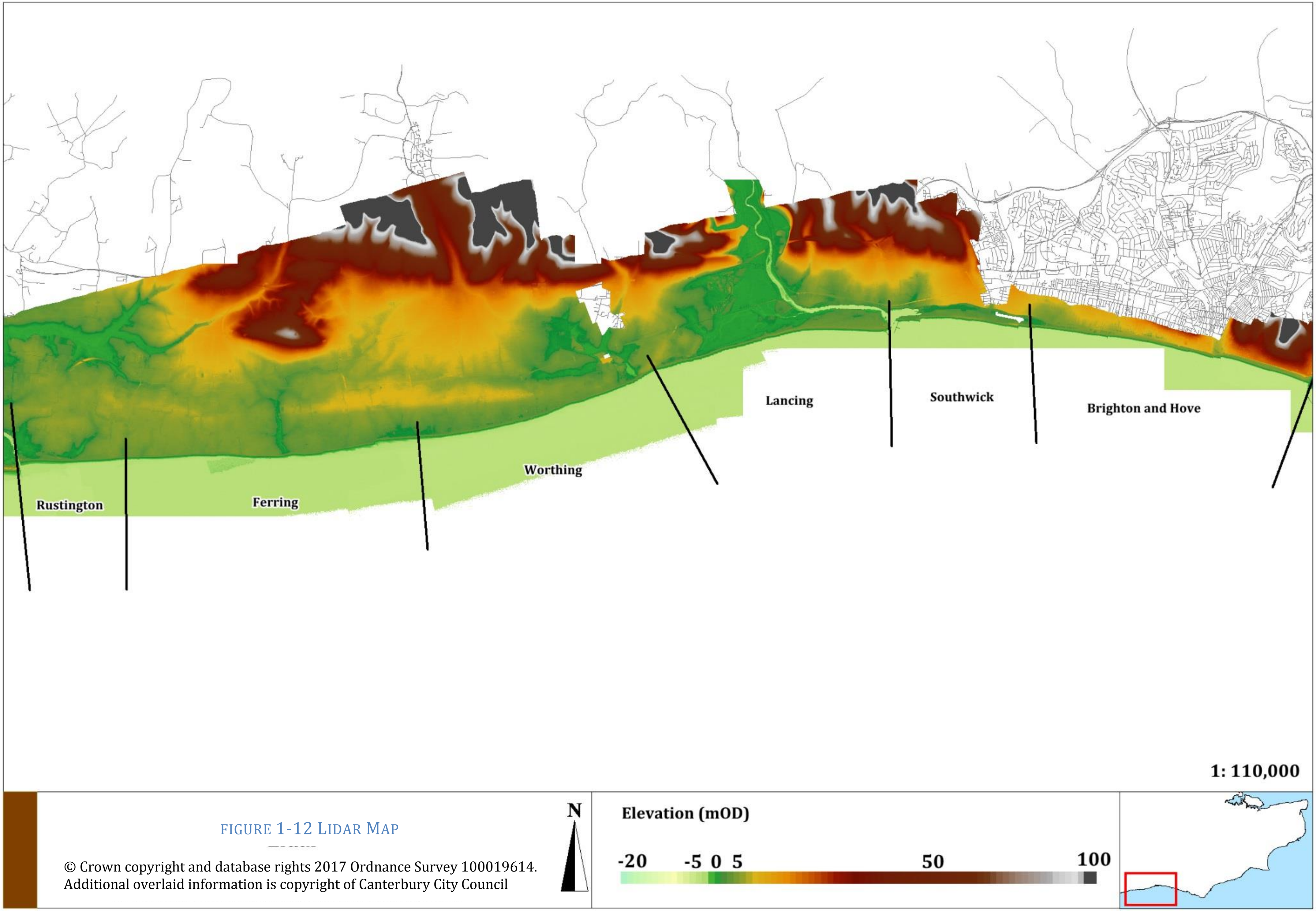

FIGURE 1-12 LIDAR MAP

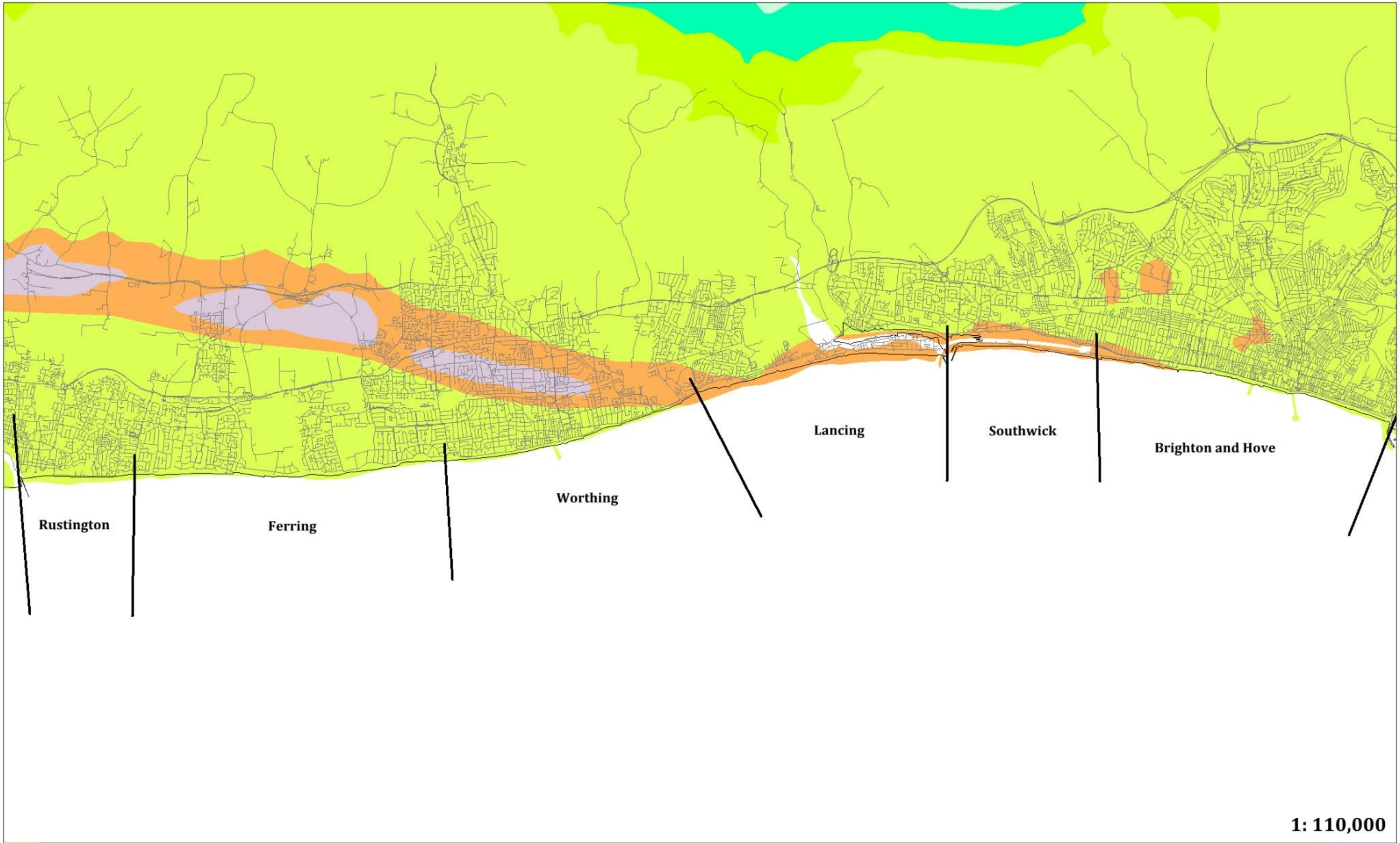

FIGURE 1-13 GEOLOGY - BEDROCK

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WHITE CHALK SUBGROUP	LOWER GREENSAND GROUP
LAMBETH GROUP	GREY CHALK SUBGROUP
THAMES GROUP	GAULT & UPPER GREENSAND FORMATION

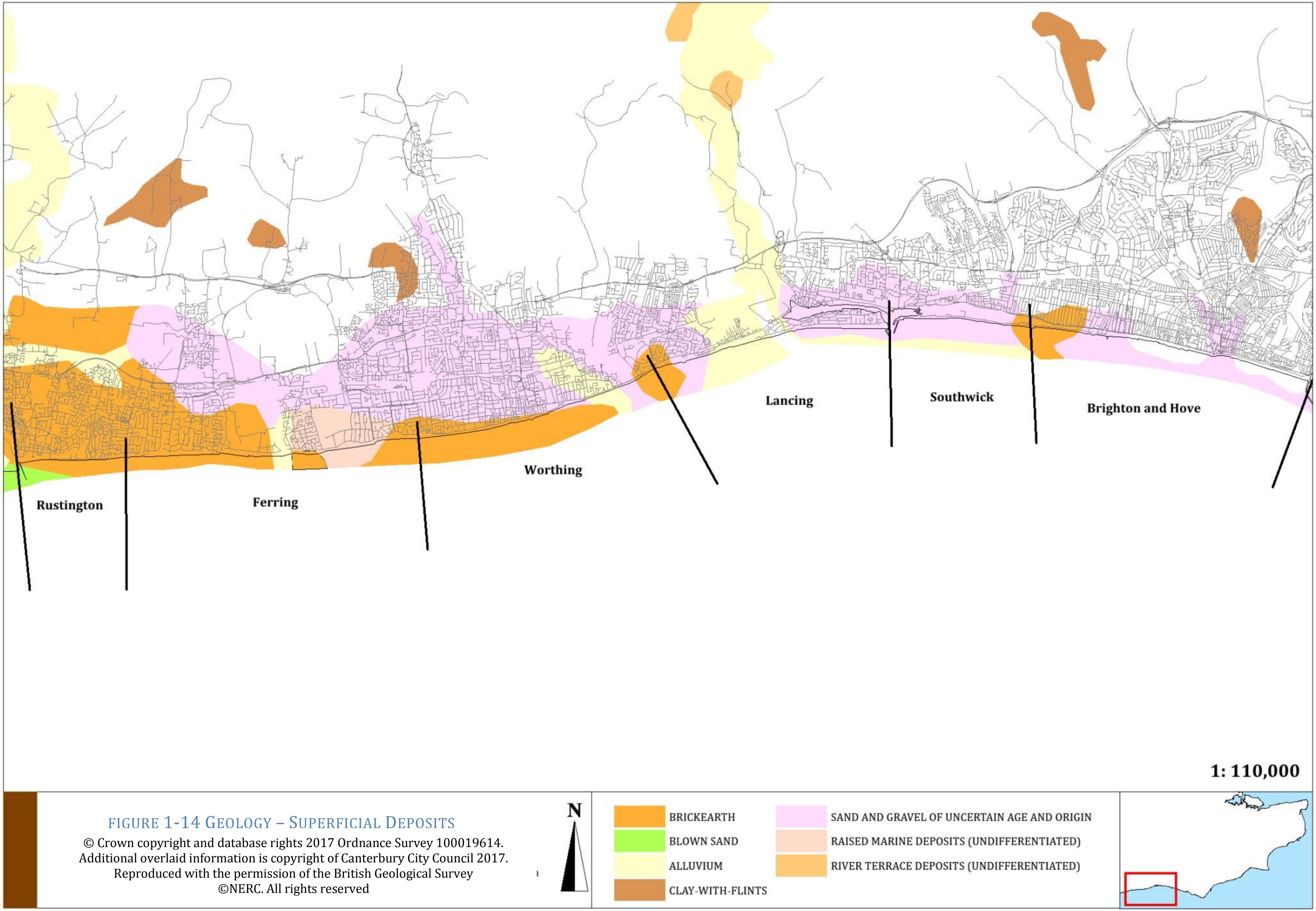

FIGURE 1-14 GEOLOGY – SUPERFICIAL DEPOSITS

1-2 HISTORY OF THE FRONTAGE

1-2-1 FLOODING INCIDENTS

Table 1-2 lists the flooding and storm events between Littlehampton and Brighton Marina. As these reports are typically in the mainstream press they frequently lack detail on the total number of properties affected and extent of damage, however this is sufficient to provide a threshold to aid validation of overtopping calculations.

TABLE 1-2 COASTAL FLOODING AND STORM INCIDENTS (ALL SOURCED FROM COASTAL DEFENCE STRATEGY- RIVERS ARUN TO ADUR, 2015)

DATE	LOCATION	DESCRIPTION
2 FEB 1983	LITTLEHAMPTON	TIDAL FLOODING. 95 HOUSES FLOODED (43 HOUSES WERE SERIOUSLY AFFECTED). FIGURES EXCLUDE RESTAURANTS, WORKSHOPS. ALL BUILDINGS ON THE WEST BANK FLOODED.
25 OCT 1984	SEA LANE – GEORGE V AVENUE	MARINE FLOODING.
23-24 NOV 1984	SPLASH POINT -	FLOODING OF GARDENS, SHINGLE/DEBRIS.
	BEACH GREEN, LANCING, & CHURCH OF THE GOOD SHEPHERD,	BREACHING OF BREASTWORK. 30 PROPERTIES FLOODED 20 GARAGES FLOODED DAMAGES £159,000 (1984 BASE).
	SEA LANE – GEORGE V AVENUE	GREENSWARD FLOODED TO DEPTH OF LESS THAN 225MM. FLOODING OF PROPERTIES.
	WEST PARADE & MARINE PARADE	OVERTOPPING, FLOODING OF PROPERTIES AND ROAD – CAUSING CLOSURE.
	BROOKLANDS	FLOODING, WITH SHINGLE AND DEBRIS COMPLETELY BLOCKING BRIGHTON RD.
8 APR 1985	BROOKLANDS	FLOODING AND SHINGLE ON BRIGHTON RD.
	BROUGHAM ROAD	ROAD PARTIALLY BLOCKED, SHINGLE ON ROAD AND ESPLANADE.
	WEST PARADE & MARINE PARADE	FLOODING OF ROAD.
16 OCT 1987	SEA LANE – GEORGE V AVENUE	MARINE FLOODING.
14 DEC 1989	SEA LANE – GEORGE V AVENUE	MARINE FLOODING.
25 JAN TO 28FEB 1990	BROOKLANDS	OVERTOPPING, FLOODING, SHINGLE/DEBRIS ON ROAD. BRIGHTON RD CLOSED.
	BROUGHAM ROAD	FLOODING, OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE/ESPLANADE. SOME PROPERTIES WERE FLOODED. SERIOUS DAMAGE TO TIMBER BREASTWORK AND UNDERMINING OF SEAWALL.
	WEST PARADE & MARINE PARADE	CONSIDERABLE OVERTOPPING & FLOODING.

	SEA LANE – GEORGE V AVENUE	OVERTOPPING AND FLOODING OF HINTERLAND, ROAD AND SOME PROPERTIES SLIP FAILURE OF EMBANKMENT.
1-3 JAN 1991	WEST PARADE & MARINE PARADE	FLOODING AND OVERTOPPING, SHINGLE AND DEBRIS ON PROMENADE. EXTENSIVE SHINGLE LOSS IN PLACES – SEA WALL UNDERMINED.
	SEA LANE – GEORGE V AVENUE	EXTENSIVE FLOODING DUE TO OVERTOPPING AND WATER SEEPING THROUGH BANK. SHINGLE AND DEBRIS DEPOSITED ON PROMENADE AND ROUNDABOUT.
30 AUG 1992	BROOKLANDS	OVERTOPPING, SHINGLE/DEBRIS OVER PATH.
	WEST PARADE & MARINE PARADE	OVERTOPPING, SHINGLE/DEBRIS ON PROM.
	SEA LANE – GEORGE V AVENUE	FLOODING NORTH OF BEACH SHELTER. MATERIALS WASHED OUT OF BANK. AREA OF GREENSWARD FLOODED.
25 OCT 1992	BROOKLANDS	FLOODING, UNDERMINING OF PROPERTIES.
9-11 JAN 1993	BROOKLANDS	OVERTOPPING, FLOODING, SHINGLE/DEBRIS ON ROAD CLOSING 1 LANE.
	WEST PARADE & MARINE PARADE	OVERTOPPING, SHINGLE/DEBRIS ON PROM FOUNDATIONS EXPOSED.
	SEA LANE – GEORGE V AVENUE	BREACH OF BANK IN CAR PARK CAUSING SEVERE FLOODING OF GREENSWARD, CAR PARK AND SOME PROPERTIES.
20 DEC 1993	SEA LANE – GEORGE V AVENUE	MARINE FLOODING.
1 APR 1994	BROOKLANDS	MINOR OVERTOPPING, SHINGLE ON ROAD.
3-4 DEC 1994	BROOKLANDS	OVERTOPPING, SHINGLE ON PATHS.
	WEST PARADE & MARINE PARADE	OVERTOPPING. SEVERE CUT BACK AT BEACH SHELTER AND BEACH HOTEL.
	SEA LANE – GEORGE V AVENUE	FLOODING OF GREENSWARD, & AREA ADJACENT TO YACHT COMPOUND. SLIGHT OVERTOPPING. SEVERE CUT BACK AT YACHT CLUB RAMP AND BEACH SHELTERS.
7 DEC 1994	BROOKLANDS	OVERTOPPING, SHINGLE/DEBRIS BLOCKED ROAD AND PATHS.
	BROUGHAM ROAD	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
	WEST PARADE & MARINE PARADE	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
	SEA LANE – GEORGE V AVENUE	WIDESPREAD FLOODING OF GREENSWARD, CAR PARK, HIGHWAY, AND LAND ADJACENT TO YACHT COMPOUND.
16 FEB 1995	BROOKLANDS	EXTENSIVE OVERTOPPING, ROAD FLOODED, SHINGLE BLOCKED 2 LANES AND GULLIES.
	WEST PARADE & MARINE PARADE	OVERTOPPING, SHINGLE ON BEACH SEVERE CUT BACK OF BEACH.

	BROUGHAM ROAD	MINOR OVERTOPPING.
28-29 OCT 1996	BROOKLANDS	MAJOR OVERTOPPING, FLOODING OF ROAD AND PITCH AND PUTT COURSE ROAD BLOCKED BY FLOOD WATER AND SHINGLE - TRAFFIC DIVERTED BY POLICE.
	SEA LANE – GEORGE V AVENUE	MINOR SURFACE WATER FLOODING TO GREENSWARD.
	WEST PARADE & MARINE PARADE	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
	BROUGHAM ROAD	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
10 FEB 1997	WEST PARADE & MARINE PARADE	BEACH DEPLETION IN FRONT OF BEACH HUTS OLD BEACH TRAP EXPOSED.
3-4 JAN 1998	BROUGHAM ROAD	SHINGLE/DEBRIS WASHED ONTO PROMENADE.
	WEST PARADE & MARINE PARADE	SHINGLE/DEBRIS WASHED ONTO PROMENADE.
26 DEC-1 JAN 1999	BROOKLANDS	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
	WEST PARADE & MARINE PARADE	OVERTOPPING WITH MINOR FLOODING AND SHINGLE ON PROMENADE. BEACH DEPLETION.
26 DEC-1 JAN 1999	BROUGHAM ROAD	OVERTOPPING, SHINGLE/DEBRIS ON PROMENADE.
3 JAN 1999	SHOREHAM	OVERTOPPING, EMERGENCY WORKS ENSURED PROTECTION OF SEAFRONT HOUSES.
WINTER 2013/14	VARIOUS LOCATIONS	30 COMMERCIAL PREMISES FLOODED ON BRIGHTON SEAFRONT, FACTORIES AND WAREHOUSES FLOODED WITHIN SHOREHAM PORT, PROPERTY FLOODED AT BASIN ROAD SOUTH. ACCESS TO SEWAGE WORKS POWER STATION AND OTHER PORT TENANTS LOST FOR 18 HOURS.

1-2-2 EROSION INCIDENTS

There are no erosion incidents recorded for this frontage.

1-3 HISTORY OF COASTAL MANAGEMENT

Figure 1-17, at the end of this section of text, shows a summary timeline of these activities.

LITTLEHAMPTON TO RUSTINGTON

Historic records suggest that two piers either side of the Arun were constructed and a deep channel cut in 1735 in an effort to stop the river from silting up. These structures were rebuilt in 1823 and have been maintained ever since.

The first defences at Rustington include timber groynes, constructed in around 1867. In 1910, construction of the sea wall started along the western end of the unit. 20 years later a simple concrete sea wall was built at the eastern section of Rustington and was then extended with a stone block wall and concrete capping in the late 1940s. It wasn't until the 1960s that timber groynes were installed at the eastern section of Rustington, the majority of which were later replaced in 1986-87. In 1994, a rock groyne was built in order to replace an old timber groyne at the eastern end of this unit.

RUSTINGTON TO FERRING

Historic coastal management at Ferring includes the installation of timber groynes pre 1876. These groynes were not updated until the 1950s, where more timber groynes were added in the centre of the unit. Many of these timber groynes were replaced in a scheme in 1980-1987. In conjunction with this timber groyne replacement, timber breastwork was constructed at Kingston Gorse in order to protect the Blue Bird Cafe and residential properties behind as this section has a higher risk of flooding. Further timber and some rock groynes were constructed at the eastern end of the unit in 1987-88. In 1994, 5 timber groynes at the western end of the unit were replaced by 2 larger rock groynes and in the following year 4 timber groynes in the centre of the unit were updated and replaced with new timber groynes. More recently, in 2003 a shingle recharge along with the installation of new timber groynes at Ferring Rife took place in order to replenish beach levels.

WORTHING

The first timber groynes at Worthing were constructed in the early 1800s and by 1810 with further works to the esplanade (now Marine Parade) constructed between 1819 and 1821 and the retained beach acted as one of the first sea defences. Throughout the 19th century, the centre of Worthing was liable to flooding and from comparing historic maps it was estimated that the high water mark had advanced by approximately 90 m between 1857 and 1907. Sea defence policy was not consistent across the town until 1890 when Worthing was unified under one borough.

The first pile for Worthing pier was driven into the seabed on July 4th 1861. It officially opened in April 1862 and was a basic iron structure, 960ft long and 16ft wide. In 1888-89 it was enlarged, a pavilion added and strengthening works were undertaken. In 1913, the pier was hit by a severe storm causing the destruction of part of the decking between the pavilion and the shoreline. Repair works were undertaken and was reopened to the public in 1914. The pier was repaired several more times between 1914 and 1949 when finally it was refurbished using recycled cast iron water mains as piles due to the lack of materials after the Second World War.

A concrete sea wall was constructed at the western end of the unit during the 1920's.

In the 1950s-1960s the middle-west of Worthing saw timber groyne construction, with the rest of the frontage having groynes constructed in the late 1980s/ early 1990s.

As part of a large capital scheme, splash point was constructed in the 1990s, consisting of a sea wall with a rock revetment fronting the point. Prior to this large scheme a rock revetment was constructed in 1989 at Ham Road. This was in response to emergency works which were carried out after damage to the sea wall. The revetment is 130 m long and built to a height of +5.5 mOD. Both structures have enhanced coastal planshape discontinuities.

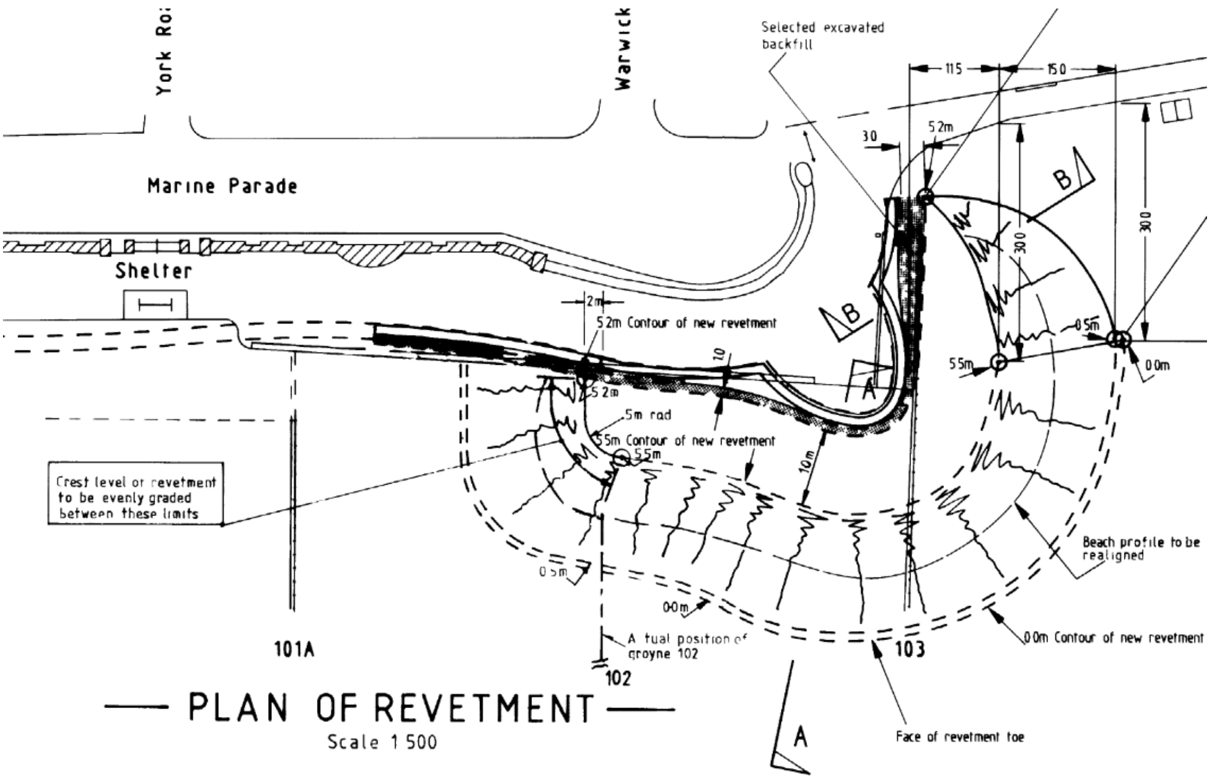

FIGURE 1-15 SPLASH POINT, CONSTRUCTED IN 1990.

LANCING

The history of Lancing and Shoreham Beach is tied to the evolution of the shingle spit (Coastal Evolution, Geology Section 1.1.3). There have been several natural and artificial breaches throughout time however due to the high transport rate these have been quickly filled in. SCOPAC (2008) reports:

"Between 1700 and 1760 there was almost 2 km of eastward spit migration, leaving New Shoreham - built in the eleventh century because of channel siltation up-estuary - some 1.3 km from the entrance to the Adur. A new channel, opposite Kingston-by-Sea (Southwick), was cut in 1762, piers were constructed and the former river mouth closed off. This proved ineffective, requiring a new channel some 0.6 km eastwards in 1783. Poor maintenance quickly rendered this entrance un-navigable and the spit migrated 30 to 40 m a^{-1} eastwards during the subsequent 35 years. Prompted by concerns of economic decline, the 1762 channel was re-opened in 1818 and provided with substantial training walls (Brookfield, 1949). Dredging was thereafter undertaken regularly to avoid shoaling, and the former river channel east of Kingston was converted to a canalised harbour basin in the 1850s."

The modern day harbour entrance, east and west breakwaters were constructed in 1957 as part of major works to the harbour. The harbour entrance has provided a block to sediment transport and as a result sediment accumulates west of the outlet. This material has been exported as an aggregate source, historically providing 90,000m^3 per year of material.

In 2000, a large capital scheme provided 33 rock groynes, modifications to existing timber groyne and 500,000 m^3 of beach nourishment. This was in order to combat erosion and prevent the spit from breaching, thus providing flood protection to Lancing and Shoreham. A pipe was installed linking the Widewater saline lagoon to a fresh source of salt water so that the works did not impact on the biota within the lagoon.

SOUTHWICK

Southwick has undergone sediment starvation since the construction of the breakwaters at the harbour entrance in the 1880's. To maintain the beach at Southwick a combination of activities has been undertaken; "groyning (dating from c.1870), deposition of dredged spoil, rubble dumping and recharge with excess gravel accretion up-drift of the western breakwater" SCOPAC, 2008.

Dredging spoils, from the harbour, were placed on the beach between 1954 and 1957 (Sir William Halcrow, 1967) however the small grade of the material meant that much of it was quickly washed away. SCOPAC (2008) reported that in the twentieth century sediment loss would have been greater but for frequent nourishment of gravel and rubble (from urban waste) between about 1970 and 1985.

Shoreham Port Authority took responsibility for East Beach in 1987. At this stage the beach was in a depleted condition. Initially, spoil from reclamations for harbour developments were used for groyne bay infilling. Annual bypassing works have been carried out from Shoreham beach to Southwick since 1993. Approximately 15,000 – 20,000 m^3 of material is moved annually, with the exception of 2010 and 2014 which received higher amounts of shingle as material was recycled from Black Rock (the East of Brighton), in addition to the normal sites (see Figure E2-2 in Appendix E for a table of all recycling events).

BRIGHTON

Brighton is a large historic seaside town and has a long history of sea defences. The first defences were wooden groynes built in the 1720's to protect the Lower Town from storm damage, after the area had been ravaged by storms in both 1703 and 1705. The first concrete groyne was built at East Street in 1867. The Banjo Groyne, which still stands today, was built in 1877. The implementation of groynes build the beaches up greatly; Madeira drive expanded to 18 m wide in 1870, extending to 30 m wide by 1898.

Prior to the beach defences being built the sea reached the base of the cliffs at Kemp Town during high tide. The first sea wall, a simple flint structure, was built to protect against this in 1795. This was extended in 1809.

Around this time, a similar structure protected the frontage between Black Lion Street and Ship Street. This wall has been extended several times; in 1821 to West Street, in 1825-27 to East Street, in 1853 to the West Battery (in front of the Grand Hotel), and to the Brunswick Town sea-wall at the Hove boundary in 1894.

FIGURE 1-16 BRIGHTON NEW SEA WALL, KEMP TOWN 1830'S

As part of the construction of the Chain Pier in 1822-1823 a short section of a masonry sea wall was built in front of the cliffs. A concrete sea wall was constructed in 1830 – 1833 along the face of the East Cliff from the Old Steine to Royal Crescent. The defence was backfilled with rubble to the height of half that of the cliffs. Further works extended the sea wall up to Kemp Town by 1838.

More concrete groynes were added to the frontage west of the West Pier in the years 1949-1950. Nearly twenty years later timber groynes were added throughout the frontage.

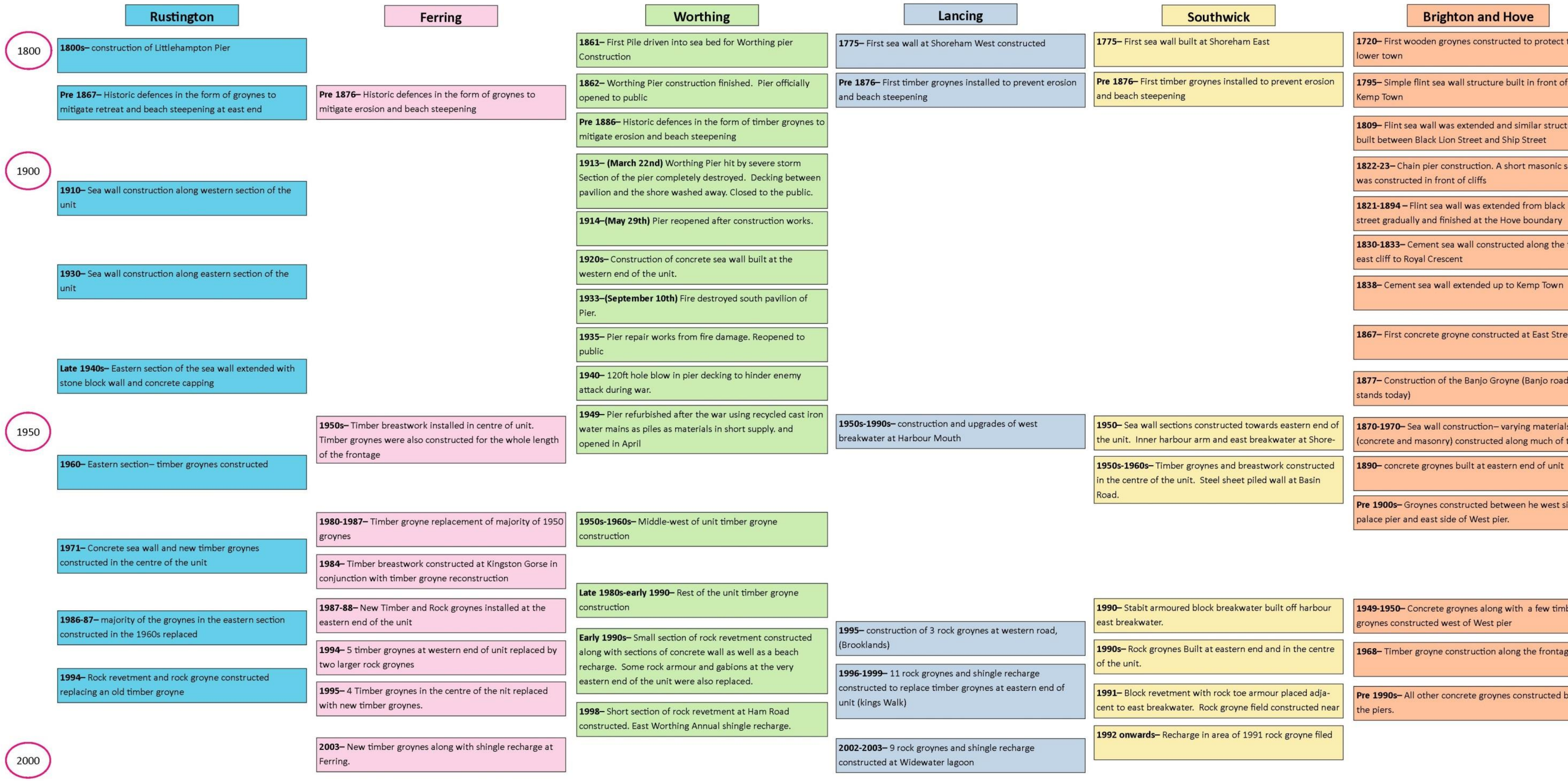

FIGURE 1-17- COASTAL DEFENCE TIMELINE

1-4 ENVIRONMENTAL OPPORTUNITIES AND CONSTRAINTS

The issues relating to the local environment are fully described in the Environmental Assessment in Appendix - B of this report. The following section provides a brief overview of the key issues within the area, affecting coastal management, for protected sites, agriculture, infrastructure, tourism and recreation, culture and archaeology.

ENVIRONMENTAL RESTRICTIONS

The **Beachy Head West Marine Conservation Zone (MCZ)** borders the Brighton unit. The presence of the site means that the planning of beach management activities must take into account any downdrift impacts onto the sensitive site. There is also an offshore site, **Kingsmere MCZ,** which similarly should be taken into account considering dredging activities. Consultation with the MMO should take place for any coastal defence works, with the exception of beach recycling.

Within the study area there are two reserves designated locally for their wildlife value. This is the **Shoreham Beach** and **Widewater Local Nature Reserve (LNR)**. The former is designated due to the large vegetated shingle community present on Shoreham West beach. Any beach management activities will need to work around this priority habitat; this may involve fencing off vegetated areas or scrapping the top layer of shingle off, stockpiling it and resurfacing it after the works. These areas are outlined in Figure 1-2-2. For more detailed information see Chapter 8 – Beach Management Guidance.

To ensure no damage is caused to the sites specific management requirements consultation with the land manager, i.e. Adur and Worthing Council and Friends of Widewater Lagoon, should be undertaken.

ENVIRONMENTAL OPPORTUNITIES

Three Biodiversity Opportunity Areas exist within the study area. No statutory protection is afforded to these sites however it is in the best interest of sustainable development that these opportunities are considered and, potentially, integrated into any proposed scheme. Figure 1-2-3 outlines these areas. More detail is given within Appendix B.

FIGURE 1-18 ENVIRONMENTAL RESTRICTIONS OVERVIEW MAP

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FIGURE 1-19 ENVIRONMENTAL OPPORTUNITIES OVERVIEW MAP

1-4-1 AGRICULTURE

There is no agricultural land bordering the coastline as the frontage is urbanised. Landward of the urbanised area the land is largely arable, yet to a lesser extent there is also a mix of pasture, deciduous woodland and golf courses. Typically the lowland is given over to arable agriculture whilst forestry and stock rearing is undertaken on the Downs. This is due to soil being more fertile on the coastal plains. Chalk grassland increased to the east behind Brighton and Hove.

1-4-2 INFRASTRUCTURE

A coastal road, the A259, extends between Worthing and Brighton.

The Brighton to Bournemouth railway line transverses the study area, running parallel to the coast. The line is generally set back from the seafront and does not come into close proximity of the shoreline.

There are three harbours within the study area. The Brighton Marina borders the eastern extent of the study area. Shoreham Port is a medium sized industrial port, handling up to 1.8 million tonnes of cargo last year (Shoreham Port Annual Report, 2015). The port is also used by fishing and leisure vessels. Littlehampton is the smallest of the three harbours – berthing up to 120 motor boats. There are three RNLI lifeboat stations situated at Brighton, Shoreham and Littlehampton.

1-4-3 ARCHAEOLOGY & CULTURAL HERITAGE

When sites of high archaeological and cultural value have been identified, they are assessed and recommendations are put forward. In England, three statutes provide protection for archaeological sites and their settings:

- Ancient Monuments and Archaeological Areas Act (AMAA) 1979;
- Town and Country Planning (Listed Buildings and Conservation Areas) Act 1990;
- Protection of Wrecks Act 1973.

There are a number of Scheduled Monuments within close proximity (<1km) of the study area. The sites are: Shoreham fort, Littlehampton Fort, Marlipins, Romano-British villa at Manor Hall Road (Southwick), Remains of old manor house (Portslade-By-Sea). The key Scheduled Monument sites to consider in beach management works are Shoreham fort and Littlehampton fort as they are situated are directly on the coastline and are the only monuments which may be directly affected (in the short term) by the works.

There are approximately 1,300 listed properties within 1 kilometre of the coast. Over 70 percent of these properties situated within Brighton.

There are no protected wrecks within the study area.

2 CURRENT RISK

An essential part of this BMP is to consider the purpose of each beach to determine the standard of protection required. The purpose of the beach is graded against four categories; protection from still water flooding, and protection against overtopping, erosion and damage to structures. The coastline has been assessed against the four hazards as summarized below. Appendix C provides detailed mapping of impacts under the following four classifications.

2-1 FLOODING

Coastal flooding can be highly destructive, damaging buildings and affecting the fertility of land. For the beach to exist for the protection from flooding the beach is reducing damage to property through flying shingle, over wash, ponding, partial breach and full breach are considered as the main impacts of flooding.

The disruption following coastal flooding can be extensive to the public, transport and agriculture. The salinity of the water can also cause issues – leading to farmers land becoming infertile and upsetting natural freshwater habitats.

The frontage between Littlehampton and Worthing shows small pockets at risk of coastal flooding (Appendix C), with flood basins shown in figures 2-2 and 2-3 which are based on the 1 in 200 year still water level with no defences. There are not flood basins between Worthing and Brighton.

2-2 OVERTOPPING

Overtopping is classed as a danger to pedestrians on the beach, promenade and road and vehicles on the road; the larger the beach the lower the overtopping. The coastline between Littlehampton and Brighton is all at risk of overtopping under severe storm conditions due to the nature of the defences with the exception being the slopes at Brighton (Appendix C).

2-3 EROSION

Damage to slopes and cliffs, property on top of the slopes and cliffs and damage to property through loss of beach are all reduced by the presence of a shingle beach (Figure 2-1). There is a cliff present West of Brighton however the properties are set back, therefore between Littlehampton and Brighton no properties are at risk of being lost to the sea (Appendix C).

FIGURE 2-1 WOODEN GROYNES AND SHINGLE BEACH FRONTING RISING GROUND, LOOKING TOWARDS FERRING FROM RUSTINGTON

2-4 DAMAGE TO STRUCTURES

The beach is reducing damage to structures includes undermining of a seawall which can lead to seawall failure and material washout from behind the wall, damage to the seawall face and crown, promenade, splash and retaining walls, revetments and lastly, damage to drainage outfalls, harbour arms and rock revetments, rock and timber groynes. A network of concrete and timber defences protects Littlehampton to Brighton; however the majority of the coastline at Ferring is undefended (Appendix C).

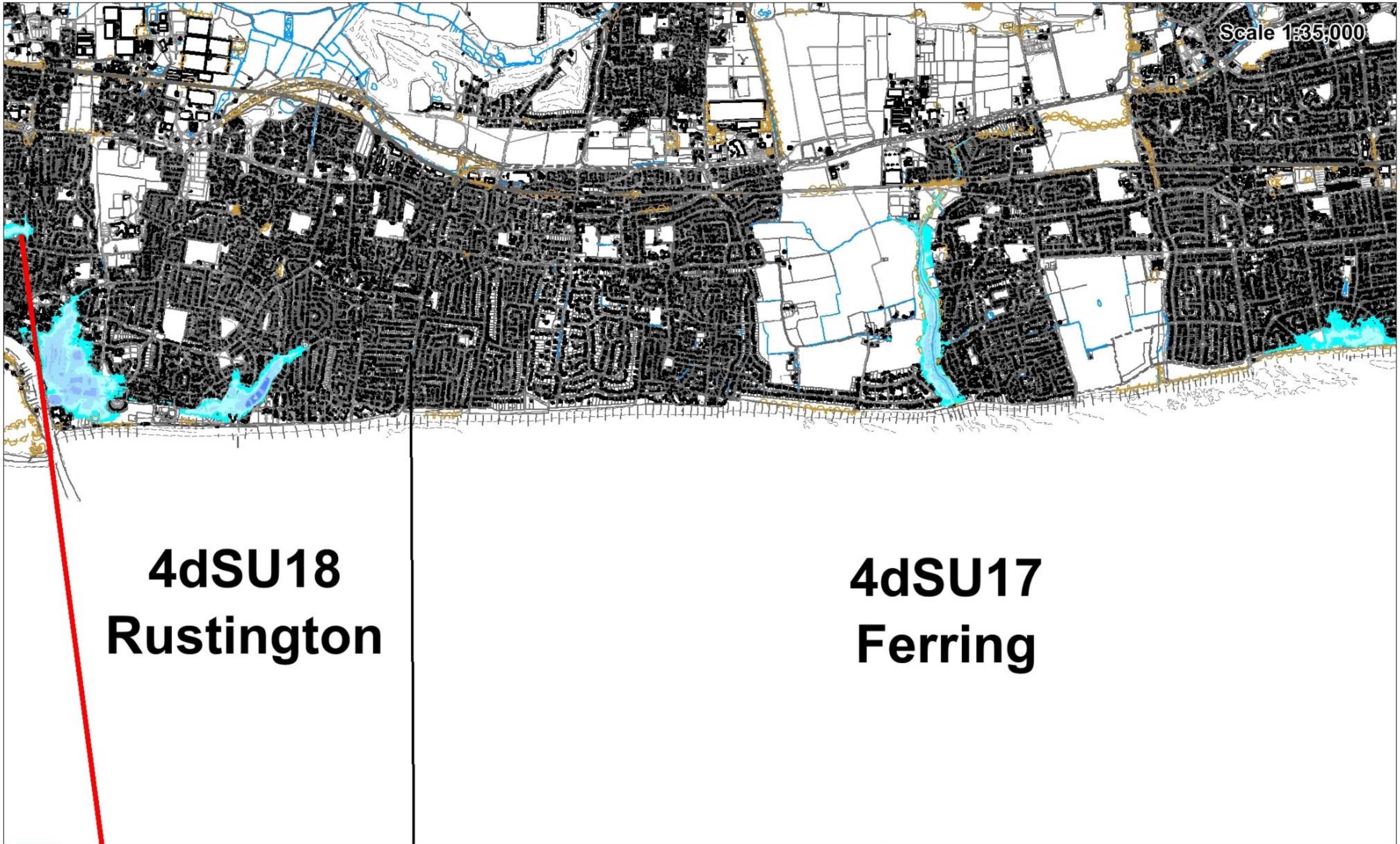

FIGURE 2-2 LITTLEHAMPTON TO FERRING FLOOD DEPTH AT 1 IN 200 YEAR STILL WATER LEVEL

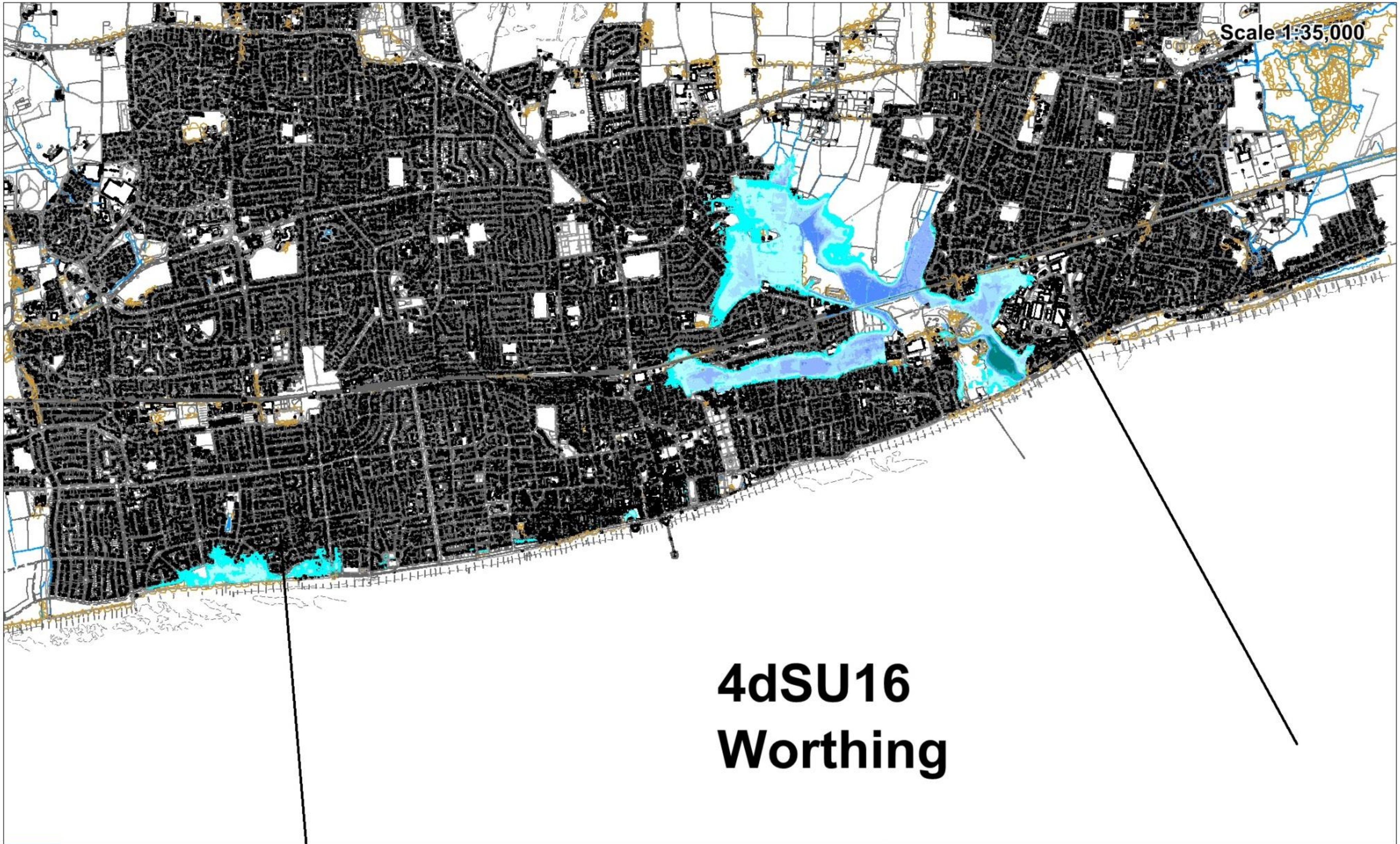

FIGURE 2-3 WORTHING FLOOD DEPTH AT 1 IN 200 YEAR STILL WATER LEVEL

N

Water Depth (m)

0.5 1.5 2.5
1.0 2.0 3.0

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2-5 AMENITY

Amenity impacts include damage to the amenity which is not infrastructure, for example reduction in beach width. Each beach has been given a score out of 100 to determine the level of amenity at risk within a 1km buffer of the coastline. The Amenity criteria are listed in Table 2-1 and a summary of the results are in Table 2-2. The calculations and thematic map are shown in Appendix C.

TABLE 2-1 CRITERIA FOR AMENITY SCALE

SCORE	DESCRIPTION
0-20	THE BEACH IS NOT EASILY ACCESSED, NO CAR PARKING, NO FACILITIES, LITTLE USAGE.
21-40	THE BEACH IS ACCESSIBLE, NO CAR PARKING, MINIMAL FACILITIES, LITTLE USAGE.
41-60	THE BEACH HAS EASY ACCESS, CAR PARKING, SOME FACILITIES AND REGULAR USAGE – MAINLY DOG WALKERS.
61-80	THE BEACH HAS EASY ACCESS, AMPLE CAR PARKING, GOOD FACILITIES, WELL USED, GENERATES SOME INCOME TO THE AREA.
81-100	THE BEACH HAS EASY ACCESS, AMPLE CAR PARKING, AND GOOD FACILITIES, IS A MAIN ATTRACTION FOR TOURISTS, HEAVILY USED, LIFEGUARDED AND RELIED ON FOR INCOME THOUGH HOTELS.

TABLE 2-2 AMENITY SCORES

LOCATION	SUB CELL	SCORE /100
LITTLEHAMPTON	HARBOUR TO SEA ROAD	59
LITTLEHAMPTON	SEA ROAD TO BROADMARK LANE	36.5
GORING	(WHOLE UNIT)	32
WORTHING	SAILING CLUB TO LIDO	40
WORTHING	LIDO TO SPLASH POINT LEISURE CENTRE	66
WORTHING	SPLASH POINT LEISURE CENTRE TO LANCING BEACH GREEN	47.5
SHOREHAM WEST	LANCING BEACH GREEN TO WIDEWATER LAGOON	48.5
SHOREHAM WEST	WIDEWATER LAGOON TO SHOREHAM HARBOUR	39.5
SHOREHAM EAST	KINGSTON BEACH	17
SHOREHAM EAST	SOUTHWICK BEACH	33.5
BRIGHTON	LAGOON TO THE MEETING PLACE CAFÉ	71.5
BRIGHTON	THE MEETING PLACE CAFÉ TO THE BRIGHTON WHEEL	82.5
BRIGHTON	BRIGHTON WHEEL TO THE MARINA	57

3 PHYSICAL INPUTS

3-1 TIDAL WATER LEVELS

Brighton has a spring tidal range of approximately 6.6metres and a neap tidal range of 2.2metres. Littlehampton has a spring tidal range of approximately 4.9metres and a neap tidal range of 1.7metres.

3-2 WATER LEVELS

Extreme water levels were taken from the Coastal Flood Boundary (CFB) conditions for UK mainland and islands report (Environment Agency, 2011). They are shown for four locations along the study area in Table 3-1and Figure 3-1.

There are two primary data sites for the CFB in the study area; Brighton Marina and the Arun Platform tide gauges. It should be noted that the outputs are heavily reliant on the modelling and interpolation between these nodes. Tidal predictions vary between software packages, namely POLTIPS (Proudman Oceanography Laboratory) and Admiralty TOTALTIDE (UK Hydrographic Office), and this may translate into uncertainty with regards the extreme sea levels.

Given that there is not sufficient historical data to validate the results, the CFB values are considered the best available data at this time.

TABLE 3-1 EXTREME WATER LEVELS (+MOD) AND RETURN PERIODS

	LITTLEHAMPTON	WORTHING	LANCING	BRIGHTON	UNCERTAINTY VALUES
1 IN 1	3.40	3.53	3.67	3.76	0.1
1 IN 5	3.57	3.70	3.84	3.93	0.1
1 IN 10	3.64	3.77	3.91	4.00	0.1
1 IN 25	3.72	3.87	4.01	4.10	0.1
1 IN 50	3.82	3.95	4.09	4.18	0.1
1 IN 100	3.89	4.03	4.17	4.26	0.2
1 IN 200	3.98	4.12	4.25	4.34	0.2

Values taken from Coastal flood boundary conditions for UK mainland and islands (Environment Agency, 2011)

Extreme water levels increase from east to west along the frontage with a typical difference of at least 360mm between Littlehampton and Brighton Marina.

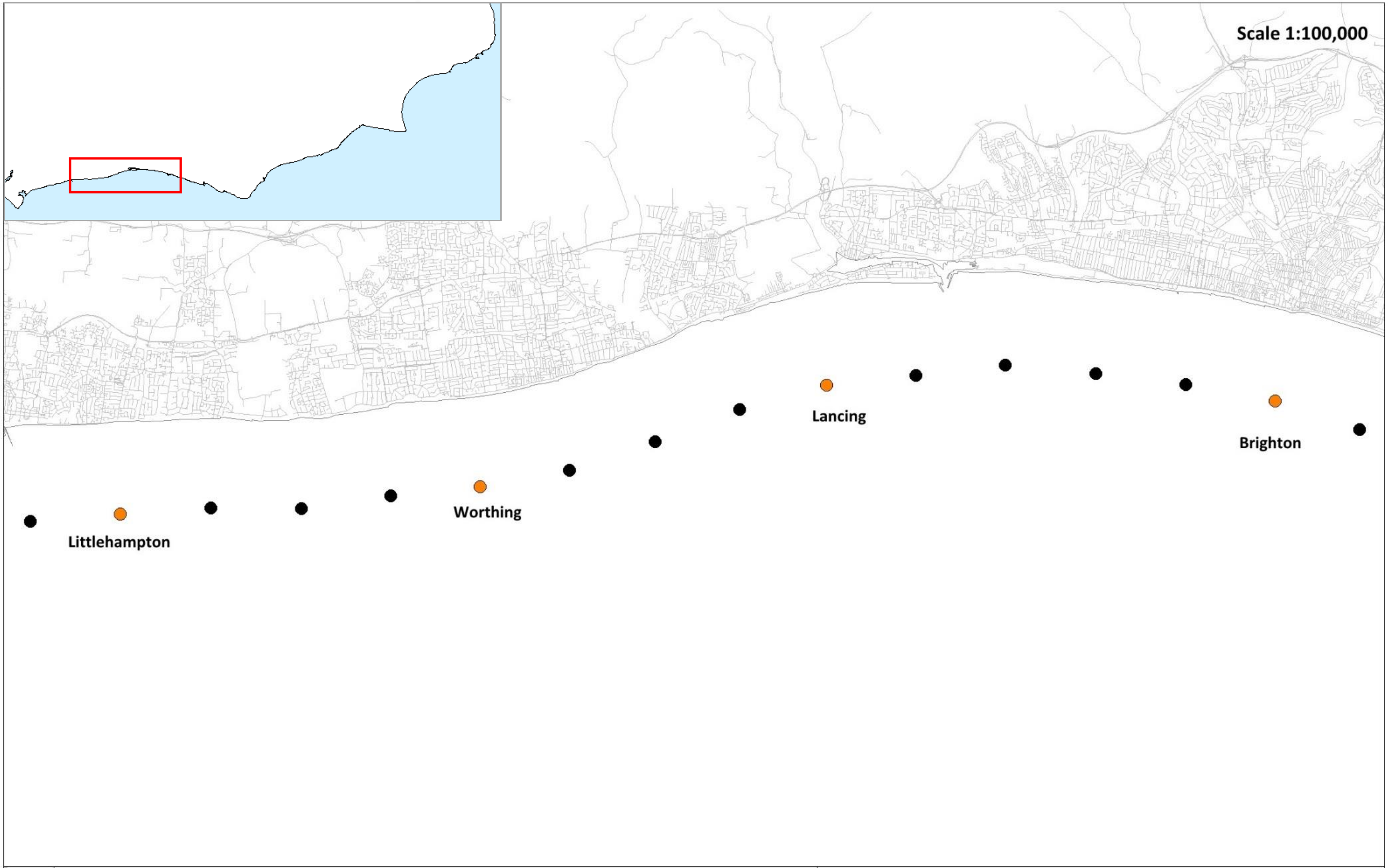

FIGURE 3-1 LOCATION OF EXTREME WATER LEVELS (EWL) AND EXAMPLE POINTS

3-3 WAVES

The wave climate is dominated by waves from the south-west (Figure 3-3), resulting in a west to east drift of beach material along the whole frontage. Waves from the South-west are more frequent and typically larger in magnitude, but it should be recognised that periods of waves from the South-East can result in a temporary reversal in the sediment drift direction.

Two sources of data have been used for this study; measured data from the Rustington and Seaford WaveRider buoys, and Met Office hindcast data that models 33 years of predicted wave conditions.

3-3-1 WAVE RECORDER

As part of the Regional Coastal Monitoring Project a network of wave buoys has been deployed around the coast since 2003.

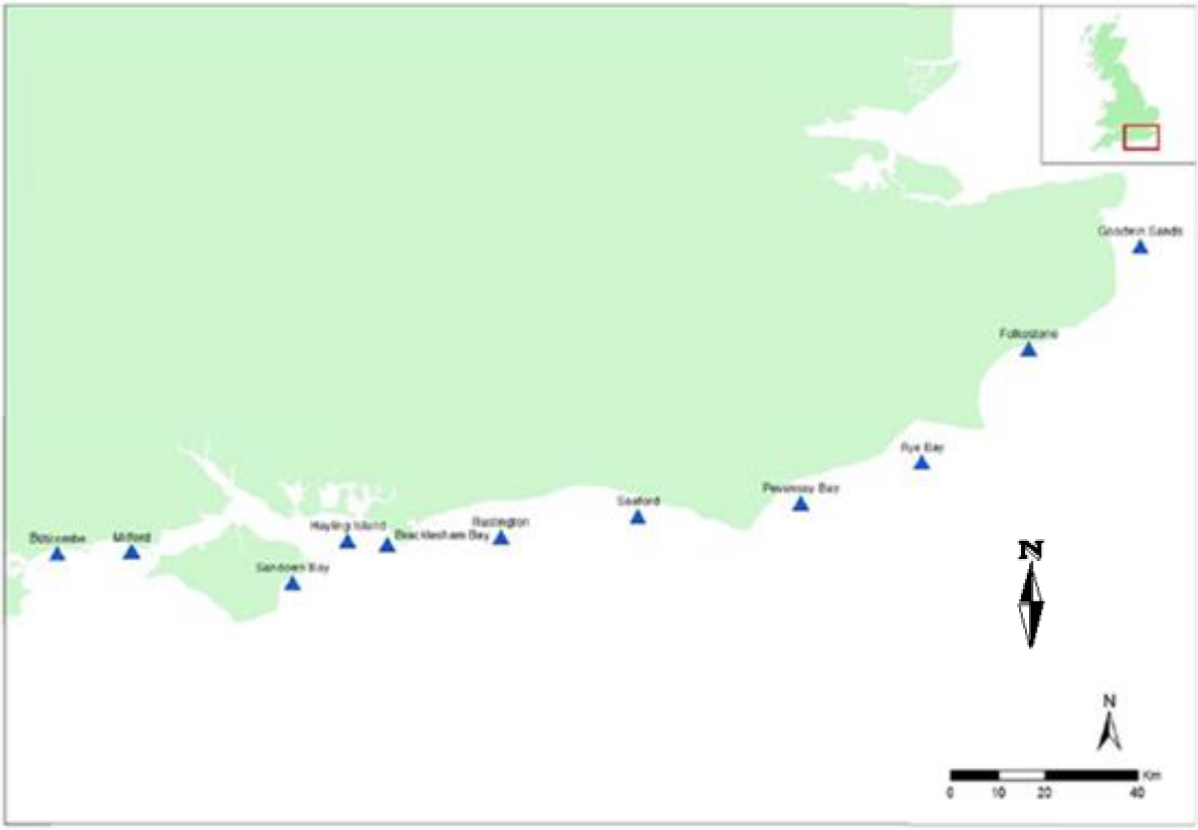

FIGURE 3-2 LOCATION OF WAVE BUOYS ON THE SOUTH EAST COAST

Directional WaveRider buoys applicable to this study are Rustington and Seaford. Rustington has been operational since 15th July 2003 to the present day and Seaford was deployed on the 22nd January 2008. Both buoys are located along the 10m CD contour and a summary of collected data is presented in the following wave roses (Figure 3-3).

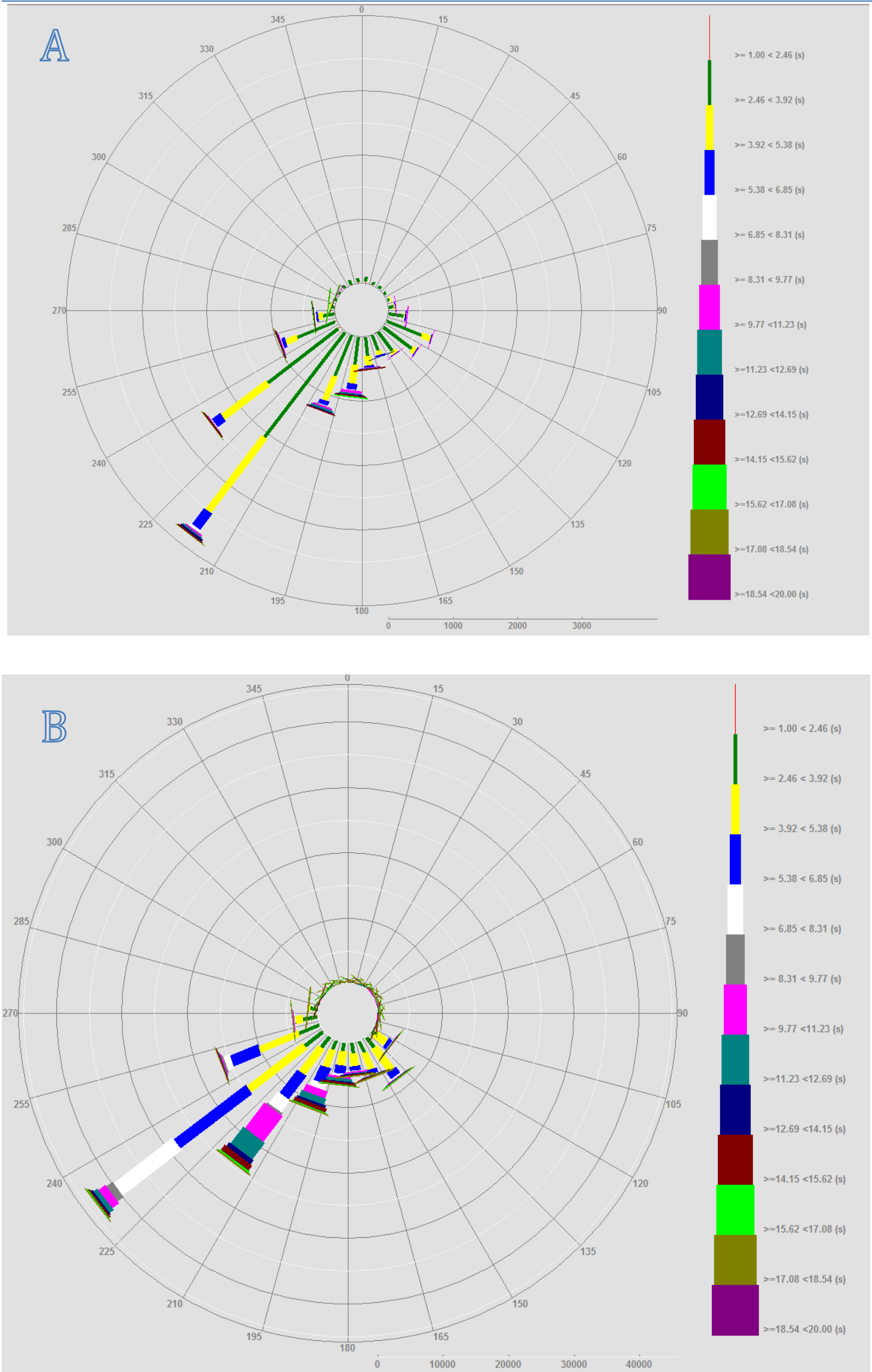

Figure 3-3 Offshore wave height (H_S) 01/01/2007 to 01/01/2017 A: Rustington Wave Rose B: Seaford Wave Rose

3-3-2 MET OFFICE HINDCAST

Using thirty-three years of Met Office Hindcast data for 52 nearshore locations at ~5km intervals (Figure 3-4) the Joint Return Probability for Beach Management study (Mason, 2014) calculated extreme return periods for each of these points.

FIGURE 3-4 LOCATION OF MET OFFICE HINDCAST POINTS

Significant wave height return periods for Met Office points M0429, M0430, M0452 and MO453 are included for reference in Table 3-2.

The methods employed to generate significant wave heights and their return periods do not take into consideration water depth and whether waves of that size could exist at that point given the effect of depth limitation. This is accounted for later in this report.

Table 3-2 Significant Wave Height, Hs (m) return periods for four Met Office Hindcast points; values in parenthesis are the water depth at this point

Return Period (1 in x years)	MO429 (15m)	MO430 (14m)	MO452 (11m)	MO453 (10m)
1 in 1	4.35	4.27	3.65	3.40
1 in 2	4.57	4.49	3.83	3.56
1 in 5	4.85	4.78	4.06	3.77
1 in 10	5.06	4.99	4.23	3.93
1 in 20	5.26	5.20	4.40	4.08
1 in 50	5.51	5.46	4.61	4.27
1 in 100	5.70	5.66	4.76	4.41
1 in 200	5.88	5.85	4.92	4.55

Contours of the annual 0.05% wave height exceedance are illustrated in Figure 3-5 and show the geographical variability within the study area suggesting very little variation in conditions between Littlehampton and Brighton.

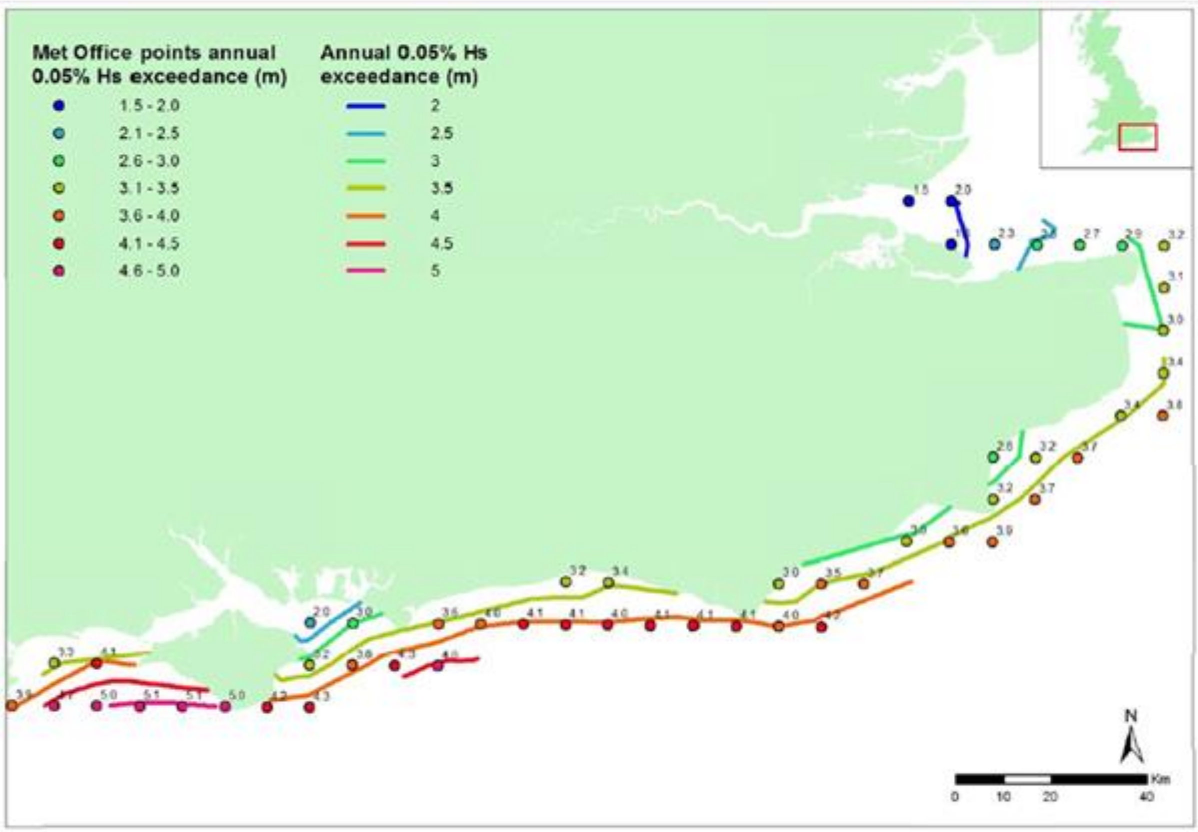

Figure 3-5 Annual Significant Wave Height (Hs [m]) 0.05% exceedance Joint Return Probability for Beach Management (Mason, 2014)

3-4 JOINT PROBABILITY ANALYSIS

Joint return periods were established using the 33 year Met Office Hindcast data and results from the EA water level boundary set as part of (Mason, 2014). These were calculated for 1, 2, 5, 10, 20, 50, 100 and 200 year return periods, using the HR Wallingford TR2 SR653 desk calculator, for each Met Office point.

Results for Met office points MO429, MO430, MO452 and MO453 are presented graphically below. Note that the potential depth limitation is broadly calculated and included on the charts, but this is calculated more accurately under specific conditions later in the report.

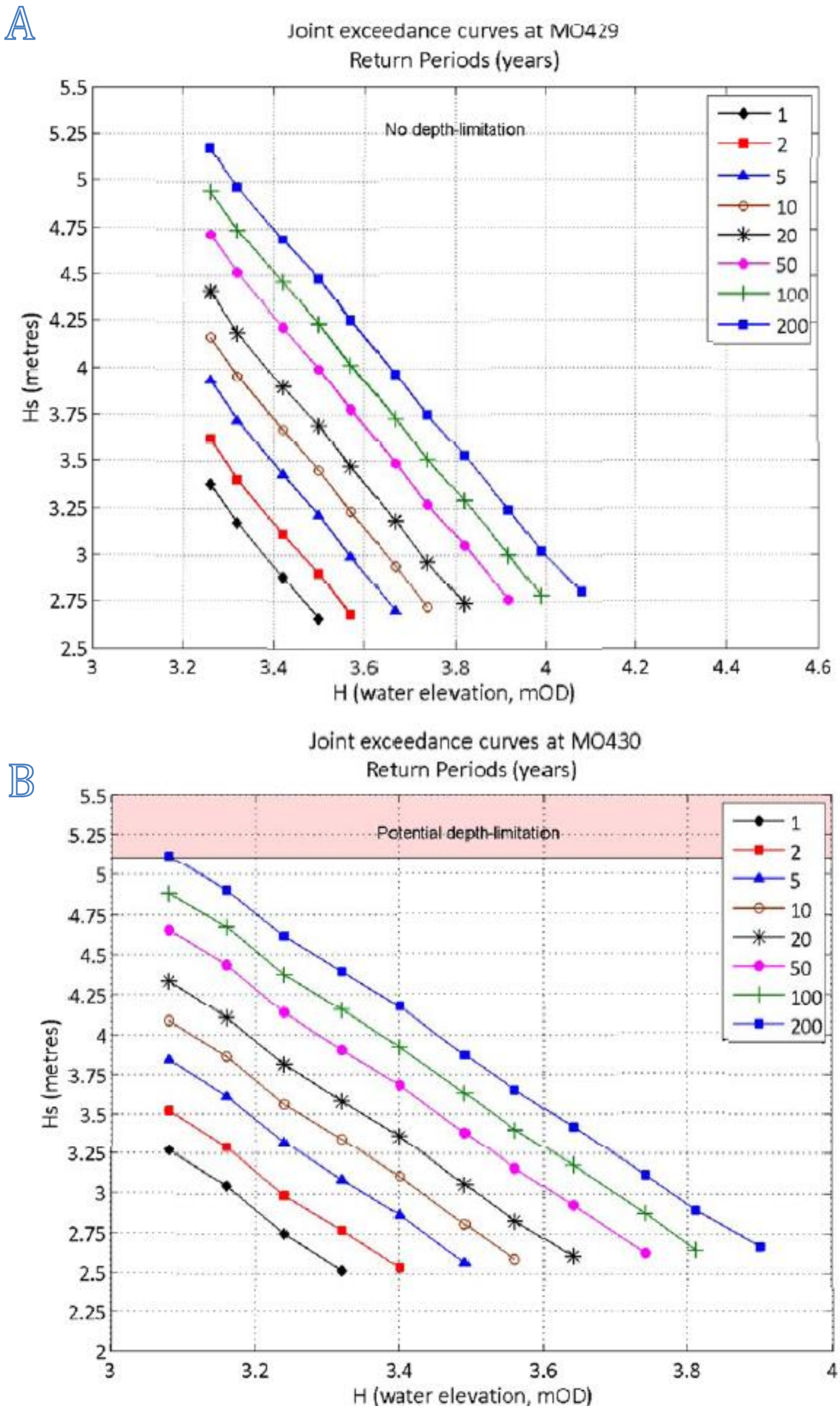

FIGURE 3-6 JOINT PROBABILITY EXCEEDANCE CURVES AT MO429 AND MO430, RETURN PERIOD (YEARS)

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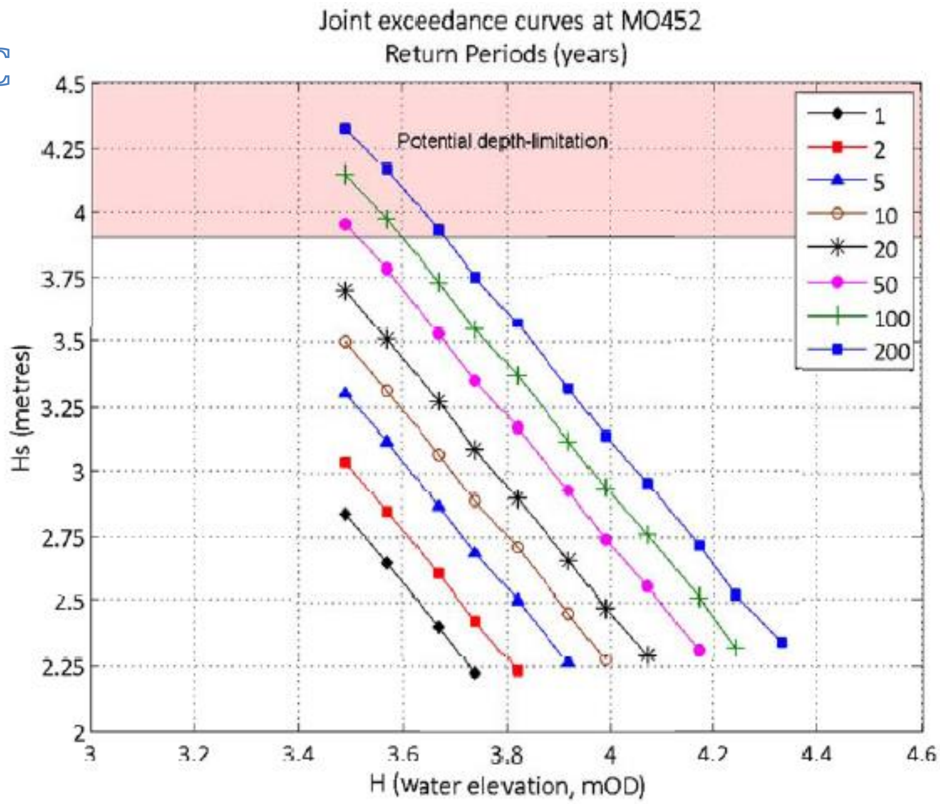

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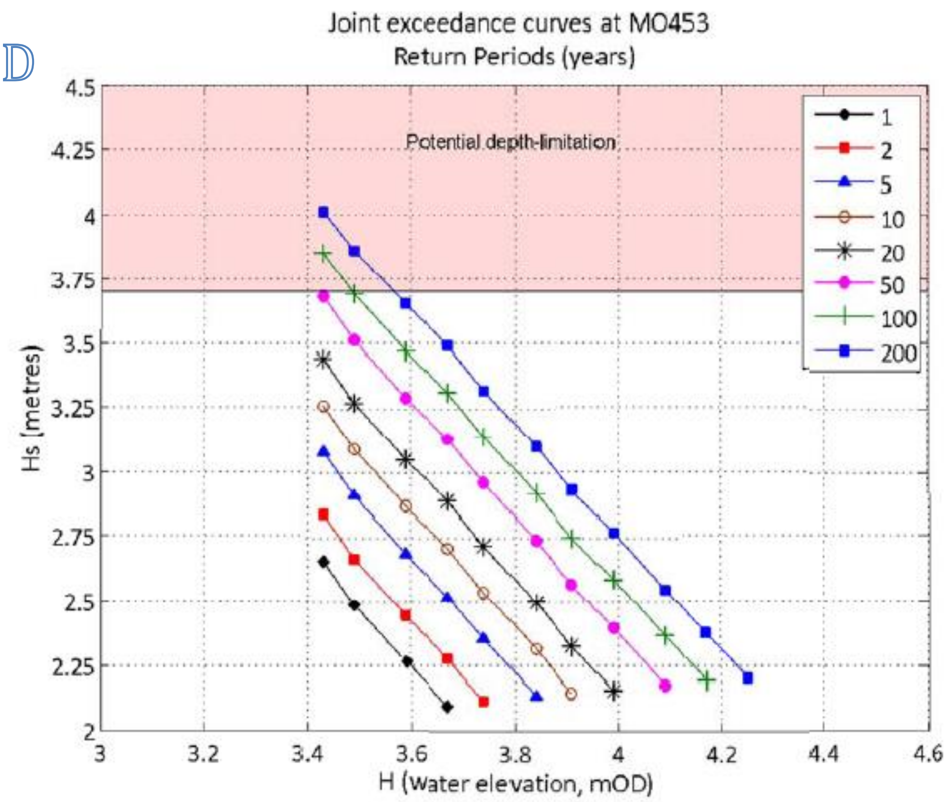


FIGURE 3-7 JOINT PROBABILITY EXCEEDANCE CURVES AT MO452 AND MO453, RETURN PERIOD (YEARS)

3-5 SEDIMENT CHARACTERISTICS

Beaches within the study area are typical of those found throughout the south east of England, comprising mixed sand and shingle sediment. There is a shingle bank present just offshore of Littlehampton. The foreshore is sandy along the frontage.

TABLE 3-3 PREDOMINANT SEDIMENT COMPOSITION OF BEACHES

LOCATION	BEACH SEDIMENT	FORESHORE
LITTLEHAMPTON TO RUSTINGTON	MIXED SAND SHINGLE	SAND
RUSTINGTON TO FERRING	MIXED SAND SHINGLE	SAND
WORTHING	MIXED SAND SHINGLE	SAND
LANCING	MIXED SAND SHINGLE	SAND
SOUTHWICK	MIXED SAND SHINGLE	SAND
BRIGHTON AND HOVE	MIXED SAND SHINGLE	SAND

Sediment grading curves are not readily available for this stretch of coastline, but visual observations would suggest the beaches are similar to other beaches within the southeast of England with a D_{50} of 10-14 mm. Larger material is found along parts of the beach at Brighton, averaging 15-30mm material.

It is good practice to ensure that the grading envelope of the replenished material is as close to the natural beach material as possible. Therefore it is recommended that a contract grading envelope is used for all works and that the delivered material is monitored to ensure it meets the specification and avoids performance issues associated with sub-standard finer material.

3-6 BEACH GEOMETRY

The coastline between Littlehampton and Brighton Marina is largely south facing, ranging from south-south-east at Littlehampton to South-South-West at Brighton. Figure 3-8, overleaf, identifies the orientation of the coastline in relation to due north (i.e. 90 degrees indicates a directly South facing beach).

Orientation is one of the factors which affect the rate of longshore transport as the dominant waves approaching from the south west tend to strike the coast at a more acute angle which promotes west to east drift. Conversely, waves from the east strike the coast closer to perpendicular which reduces the amount of material that is transported back in a westerly direction.

FIGURE 3-8 COASTAL ORIENTATION MAP (BEARING FROM DUE NORTH)

4 HISTORICAL MONITORING

4-1 CONTROL NETWORK

A control network was set up by Longdin and Browning for the Regional Coastal Monitoring Programme (RCMP) in 2003, covering the coastline between Littlehampton and Brighton Marina. It includes several E1 (surveyed for longer than 8 hours) and E2 pins (surveyed for 6 to 8 hours) which are both suitable for levelling and GPS surveys; their location is shown on the Location Map of Survey Pins overleaf. GPS equipment has an accuracy of +/- 15mm in the vertical and +/- 20mm in the horizontal.

The E1 stations at Chichester, Newhaven and Hastings are Trimble NetR5 or NetR9 Continually Operating Reference Stations that enable survey teams to connect to receive GPS corrections in real-time or if undertaking post processing or extending our control network, RINEX data can be downloaded directly from these stations or from channelcoast.org
http://www.channelcoast.org/data_management/real_time_data/charts/

4-2 TOPOGRAPHIC SURVEYS

Coastal monitoring is undertaken annually through the Regional Coastal Monitoring Programme; its primary aim is to provide a repeatable and cost effective method of monitoring the English coastline. The survey programme covers approximately 1,000km of open coastline and estuaries between the Isle of Grain and Portland Bill. Data are collected by Local Authority in-house teams and are freely available via the Channel Coastal Observatory, which is based at the National Oceanographic Centre (NOC) in Southampton. The same applies to the LIDAR data collected by the Environment Agency.

4-2-1 GPS

The elevations of the beaches between Littlehampton and Brighton Marina have been surveyed using a number of techniques since the RCMP project began. ABMS Photogrammetry was used between 2001 and 2006 at a contact scale of 1:5,000 and 1:3,000, ATV GPS survey and profiles were undertaken between 2007 and 2011, and since 2012 ATV-mounted mobile laser scanning has point clouds of all the beaches. This data is then processed to provide a 3-D model of all the beaches and profile data are extracted.

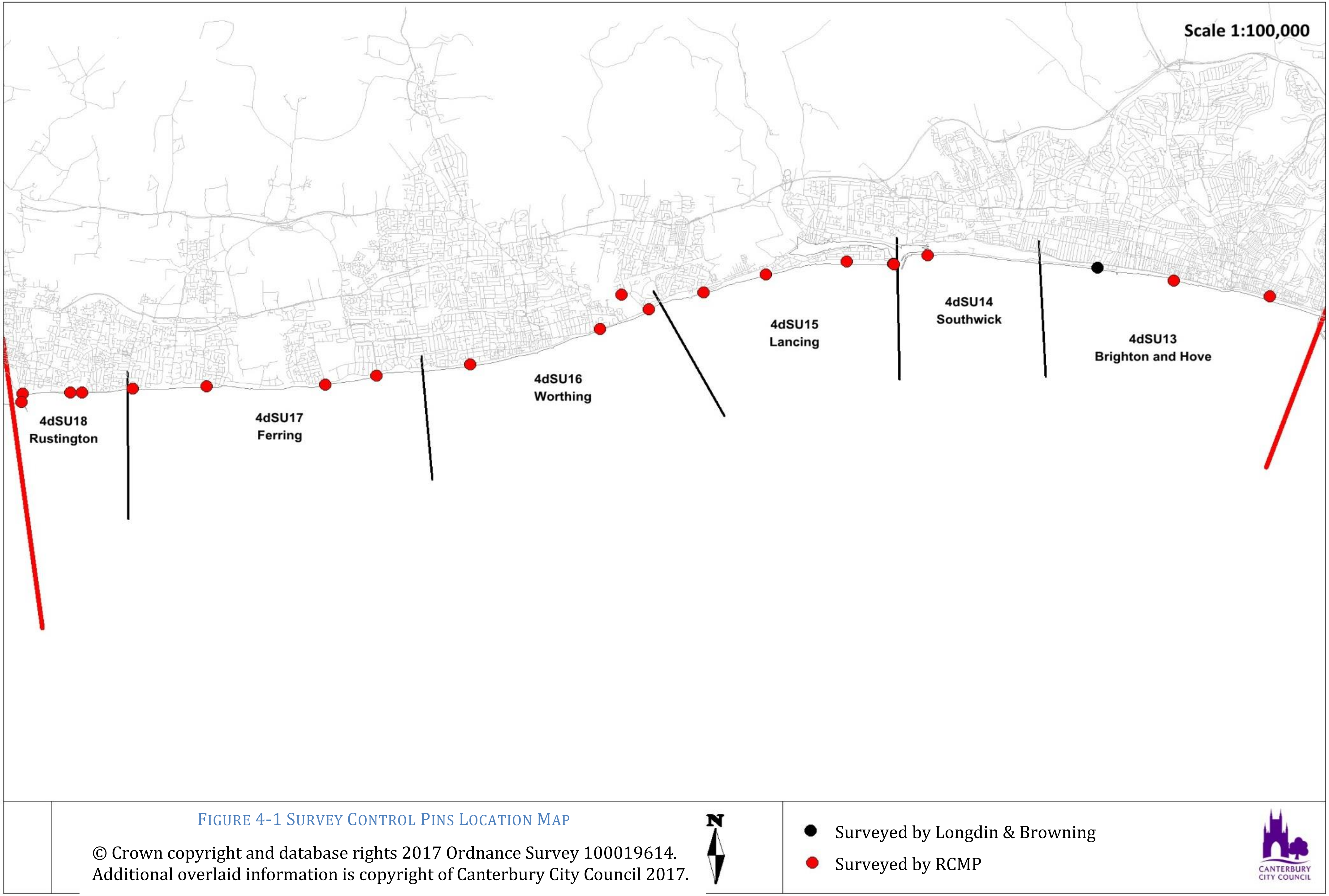


FIGURE 4-1 SURVEY CONTROL PINS LOCATION MAP

SPRING & AUTUMN SURVEYS

Historically, designated profiles were surveyed during the spring and autumn, 2003 to 2012. Since 2012 ATV Laser Scan techniques has provided a full DTM survey for each spring and autumn. Profile data has been analysed to monitor beach response to wave conditions or replenishment schemes.

SUMMER SURVEYS

Prior to 2012 a full survey was conducted to provide a 3D model of the beaches once every five years, unless the survey unit is a Beach Management Plan Site where it would be surveyed annually. This survey included a full set of profiles and a continuous dataset of the beach and foreshore. Since 2012 ATV-mounted laser scanning provides full coverage, 3D datasets together with profiles along BMP sites; however this summer survey was removed from the programme in 2017.

POST STORM SURVEYS

Historically, following a series of storm waves which exceed the storm threshold as set by Channel Coastal Observatory, post storm surveys may be conducted as an additional set of data. The surveys have only been conducted if the Local Authority or Environment Agency managers deemed them necessary as the beach to showed significant damage i.e. large losses or severe drawdown of material which will not return over the course of the next few tidal cycles.

Since 2012 these post storms have been surveyed using the mobile laser scanner which is either concentrated in the specific areas of concern or the whole beach.

IN/OUT SURVEYS

Pre 2017, In and Out surveys refer to the pre and post work surveys respectively. The profiles and/or continuous is concentrated on those areas specified by the Local Authority or Environment Agency manager; usually the extraction and deposition sites.

4-2-2 HISTORIC

ABMS

Topographic profile lines have been derived from the photogrammetry recorded under the Annual Beach Monitoring Survey (ABMS) since 1973. This data covers 440km of South East coastline for the Environment Agency's coastline. This project has also contributed to the extensive photography of the coastline and provides a long term record of coastal evolution.

4-3 BATHYMETRY

The most recent bathymetry data is the 2013 multi-beam survey. Single beam surveys of the study site were undertaken in 2007 and 2004. EGS are currently (as of April 2016) undertaking a multi-beam bathymetric survey between Shoreham and Selsey.

4-4 BMP SITES

Survey units 4dSU14, 4dSU15 and 4dSU16 (Southwick, Lancing and Worthing respectively) are BMP sites which historically received three surveys per year. Spring and autumn survey windows were February to April and September to November respectively. Summer surveys were undertaken between June and September. Each survey unit should have a minimum of two months between each survey (Profile Location Maps are included in Appendix D).

4-5 AERIAL SURVEYS

4-5-1 AERIAL PHOTOGRAPHY

As part of the RCMP ortho-rectified aerial photography is flown in the summer at varying intervals. The most recent available photography was flown in 2016 and prior to that in 2001, 2003, 2008 and 2013. This is available to download from the Channel Coastal Observatory website.

4-5-2 LIDAR

Lidar has been flown annually on behalf of the Environment Agency. Sites chosen for flight are highly dependent on budget and necessity and tend to be selected on a sliding scale; areas of few coastal defences would be a high priority and headlands or heavily managed beaches through defences or maintenance are low on the priority. All LIDAR data for this frontage is available to download from the Channel Coastal Observatory website.

4-6 STRUCTURES

4-6-1 GPS

The defence structures are surveyed every five years by the in-house coastal monitoring team as part of the baseline summer surveys. The most recent structure survey was undertaken in 2012, prior to that 2007 and 2003.

4-6-2 LOCAL AUTHORITIES

Local authorities have a requirement to regularly survey coastal assets. Mott MacDonald completed a full groyne survey in early 2016 and gave some consideration to the structures.

4-7 HYDROLOGICAL MONITORING

4-7-1 WAVE RECORD

Wave buoys situated offshore at Rustington and Seaford have been collecting real time data for the significant and maximum wave height since 2003 and 2008 respectively. Data is freely available via the Channel Coastal Observatory website. Wave parameters are recorded using a Datawell Directional WaveRider Mk III buoy.

4-7-2 TIDE GAUGE RECORDS

There are several tide gauges within this study area as they are important for understanding the local tidal conditions. The real time data can be observed alongside the predicted data on the Channel Coastal Observatory website.

A tidal gauge, situated on Arun Platform, was installed in April 2008.

A pressure sensor tide gauge in Brighton Marina was installed in 2004

The Environment Agency maintains two tide gauges within Littlehampton Harbour.

4-8 ECOLOGICAL MONITORING

4-8-1 HABITAT MAPPING

The beach vegetation within the south east of England was digitised in 2011 by the University of Southampton. The habitat mapping was based on the 2008 ortho-rectified aerial photography to provide an overview to the locations of vegetation along the coast. Results from Habitat mapping based on the 2013 aerial photography will become available during 2017.

4-8-2 ECOLOGICAL MONITORING

A baseline ecological survey of the Shoreham Beach LNR was undertaken in 2009 by Dolphin Ecological Surveys on behalf of Adur and Worthing councils. This information was commissioned to provide a sound basis for management decisions and to inform a future monitoring programme. A report of this survey is freely available online.

Wetland Bird Surveys (WeBS) are undertaken once a month over winter at the Widewater lagoon LNR at Shoreham. This survey monitors non-breeding waterbirds in the UK. The principal aims of WeBS are to identify population sizes, determine trends in numbers and distribution, and identify important sites for waterbirds. The monitoring scheme is part of a national data collation and analysis run by the British Trust for Ornithology.

The Sussex Wildlife Trust undertakes an intertidal ecological survey, at Worthing Pipe, as part of the Shoresearch project. The results from this survey feed into the national database 'Marine Recorder'. Habitat, species type, distribution and diversity are recorded and some quantitative transect and quadrat surveys have been undertaken alongside the usual recording. This enables a more accurate assessment of the relative richness of shores which provides a better measure of change over time. This data is freely available from the JNCC's Marine Recorder Application.

5 SEDIMENT BUDGET

5-1 METHODOLOGY

The sediment budget provides transparent and quantitative evidence of beach losses, gains and sediment pathways, in combination with both natural and artificial movements of beach grade material. This sediment budget predominately focuses on the shingle sediment movement, as this has the most relevance to beach management operations.

Data fed into the sediment budget is supplied through the Regional Coastal Monitoring Programme and uses the full dataset (2007 to 2017). To create the budget beach surfaces were combined to create continuous terrain models (gridded at 1m) across the whole frontage, Littlehampton to Brighton Marina. With the compiled DTM's from all available survey years, it is possible create difference models from which volumetric change between two surveys can be calculated. Negative values represent erosion that has occurred between Year A and Year B, and positive values indicate accretion. Whilst these figures show an overall change in beach volume within each discrete section, it should be recognised that the data is based on the BMP survey, which is undertaken once each year and is a snapshot in time.

The sediment budget uses Equation 1 to calculate the sediment transport rate leaving the cell, and accounts for measured volume change, management activities and anticipated losses within a cell.

EQUATION 1 $$\boldsymbol{Qoutput} = -(\boldsymbol{\Delta V} - \boldsymbol{P} + \boldsymbol{R} - \boldsymbol{L}) + \boldsymbol{Qinput}$$

Where ΔV is the as surveyed volume change, P is the combined recycling (deposition) and replenishment, R is the Recycling (Extraction), L is the combined Losses from attrition and those associated with recycling and replenishment activities. Qinput in the volume transported from the up-drift cell and Qoutput is the volume of material transported to the downdrift cell. A worked example is outlined in Figure 5-1.

The detailed methodology for the production of the sediment budget is outlined in detail within Appendix E. The outputs are available in spread sheets and graphical plates, an example of which is shown in Figure 5-2. The results are detailed and complex in nature, so to aid understanding summaries of management activities, sediment transport rates, erosion and accretion for individual units and a regional summary are provided in this report.

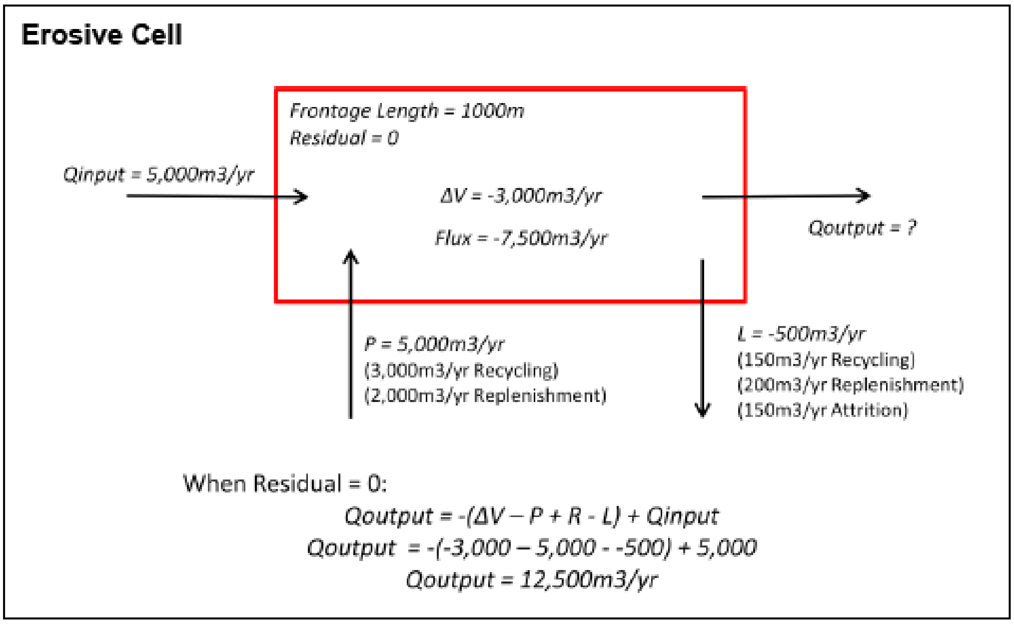


FIGURE 5-1 EXAMPLE OF AN EROSIVE CELL CALCULATED THROUGH THE SEDIMENT BUDGET

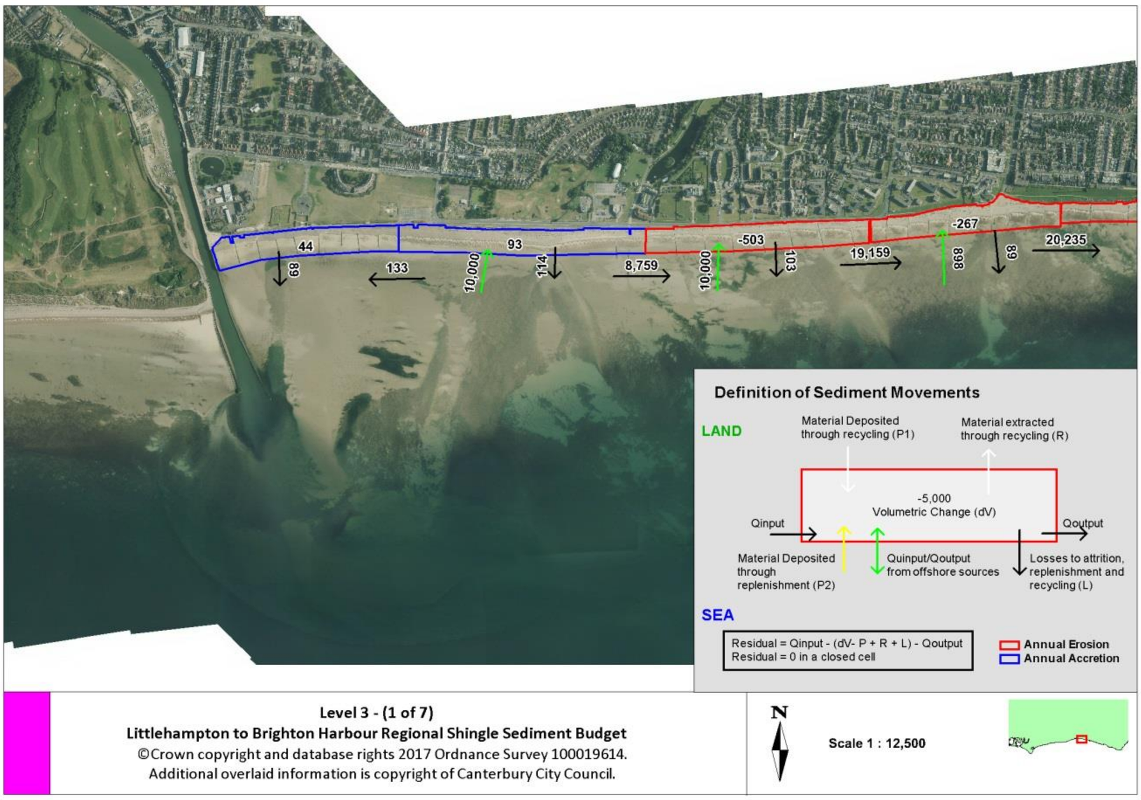


FIGURE 5-2 EXAMPLE OF DETAILED SEDIMENT BUDGET OUTPUTS (APPENDIX E)

5-2 BEACH MANAGEMENT ACTIVITIES

Current management of the beaches has been a combination of beach recycling and replenishment on an ad-hoc basis when required. A summary of the total and average annual rates are listed in Table 5-1. Full details of annual quantities and the locations of the extraction and deposition sites can be found in Appendix E.

TABLE 5-1 SUMMARY OF BEACH MANAGEMENT ACTIVITY 2007 - 2017

LOCATION	TOTAL RECYCLING VOLUME (2007-2017)	AVERAGE ANNUAL RECYCLING VOLUME	TOTAL REPLENISHMENT VOLUME (2007-2017)	AVERAGE ANNUAL REPLENISHMENT VOLUME
LITTLEHAMPTON TO RUSTINGTON	0	0	0	0
RUSTINGTON TO FERRING	610	44	0	0
WORTHING	5,715	572	0	0
LANCING	161,199	16,120	0	0
SOUTHWICK*	170,634	17,063	0	0
BRIGHTON AND HOVE	15,970	1,597	0	0
NET	354,128	35,413	0	0

(Volumes provided by coastal management authorities – figures available up until 2017

** The shingle movement at Southwick relates to the bypassing carried out by Shoreham Port)*

5-3 SEDIMENT TRANSPORT RATES

From the budget it is possible to extract average annual sediment transport rates along the whole frontage based on the data collected from 2007-2017. These demonstrate high spatial and temporal variability throughout the frontage.

Sediment budget figures have been derived from the available datasets. Figures are correct to the best of our knowledge and should be recalculated every few years.

FIGURE 5-3 SEDIMENT TRANSPORT – LITTLEHAMPTON TO RUSTINGTON

Estimated annual sediment transport in cubic meters.

Unit boundaries

N

0 | 1 - 5,000 | 5,001 - 10,000 | 10,001 - 15,000 | 15,001 - 25,000 | 25,001+

FIGURE 5-4 SEDIMENT TRANSPORT – RUSTINGTON TO FERRING

Estimated annual sediment transport in cubic meters.

Unit boundaries

0 | 1 - 5,000 | 5,001 - 10,000 | 10,001 - 15,000 | 15,001 - 25,000 | 25,001+

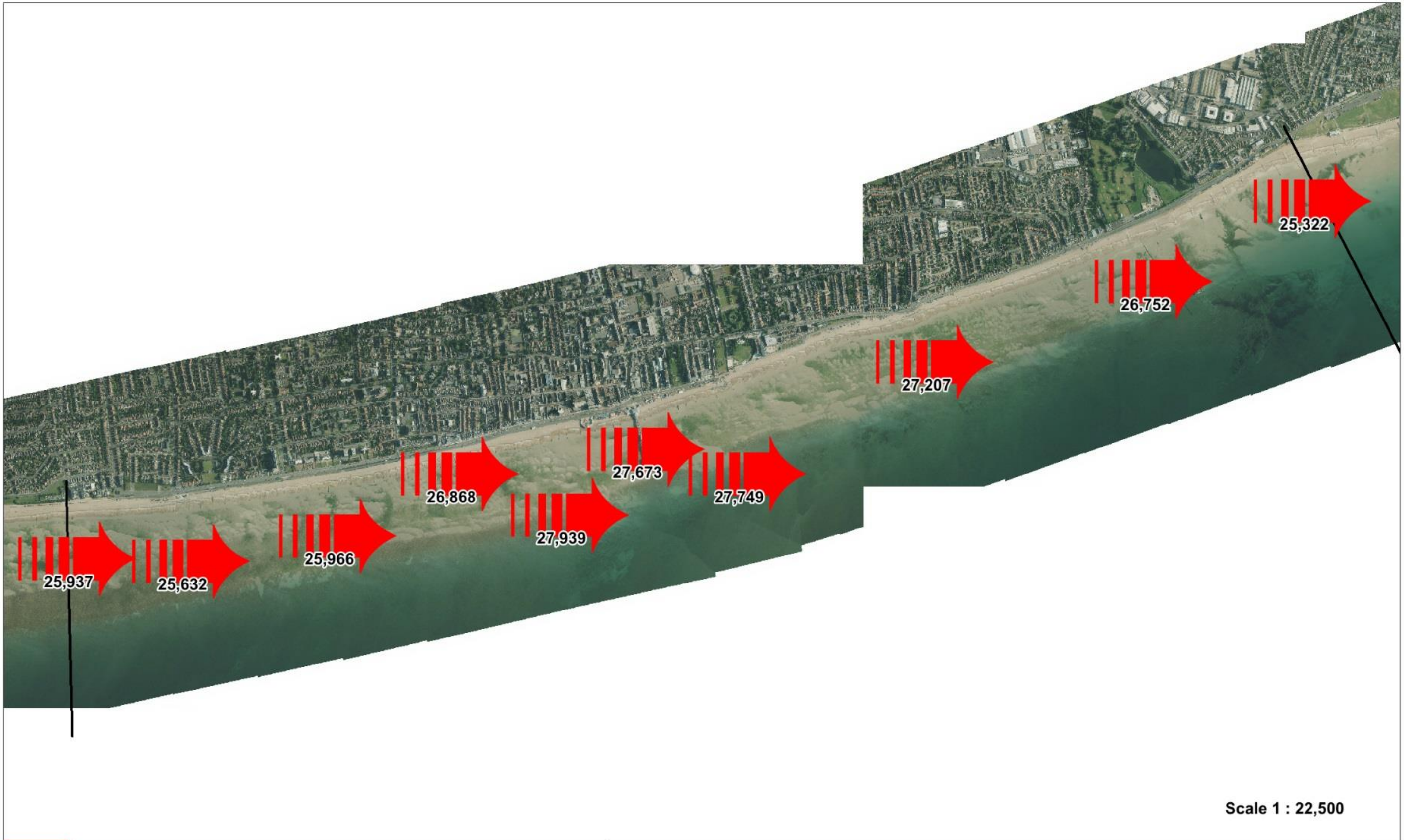


FIGURE 5-5 SEDIMENT TRANSPORT – WORTHING

Estimated annual sediment transport in cubic meters.

— - Unit boundaries

N

0 | 1 - 5,000 | 5,001 - 10,000 | 10,001 - 15,000 | 15,001 - 25,000 | 25,001+

FIGURE 5-6 SEDIMENT TRANSPORT –LANCING

Estimated annual sediment transport in cubic meters.

Unit boundaries

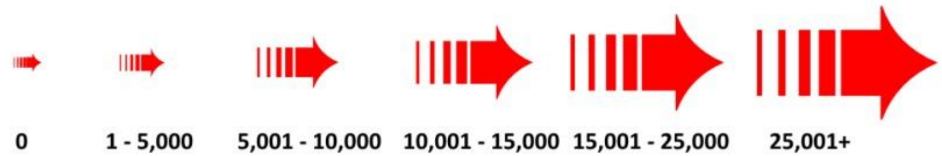


FIGURE 5-7 SEDIMENT TRANSPORT – SOUTHWICK

Estimated annual sediment transport in cubic meters.

Unit boundaries

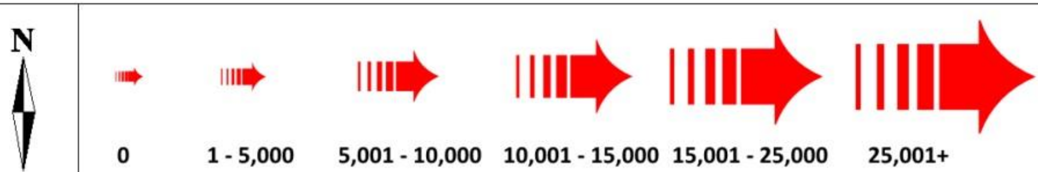
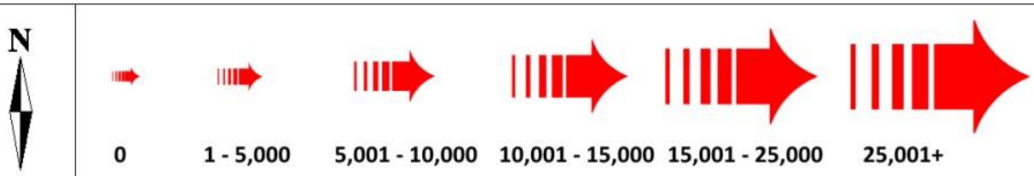


FIGURE 5-8 SEDIMENT TRANSPORT – BRIGHTON

Estimated annual sediment transport in cubic meters.

Unit boundaries



5-4 EROSION/ACCRETION

With ten years of data it is possible to establish average annual erosion/accretion patterns with a reasonable degree of confidence. Standard difference models that illustrate the difference between pairs of individual surveys are misleading in this regard for the results are influenced by any beach management activities. Replenishment and shingle recycling deposition can mask erosive areas; conversely sites used as a source of recycling material can fail to highlight accretive areas.

Using the results from the sediment budget spread sheets it is possible to calculate the Net erosion/accretion rates, discounting the effects of beach management using Equation 2. Unfortunately due to the coarse nature of replenishment/recycling logs, which usually only define volumes to within the area of the works, this can only be achieved for coarse sediment cells. However, this is usually sufficient to gain an understanding of the erosive areas, the magnitude of the problem, and identify any future sources of shingle for recycling operations.

EQUATION 2: $\boldsymbol{Net\ Erosion/Accretion = \Delta V - P + R}$

The following plates illustrate the average annual erosion/accretion across the study area discounting beach management works. Again, it should be stressed that these figures represent the average value you might expect based on 10 years of data. There can be considerable variation year on year and in some cases unusual conditions can result in a reversal e.g. an accretive area may erode due to a prolonged period of waves from a non-dominant direction.

This does however provide a basis for planning the likely necessity of beach management operations for future years based on actual recorded data.

FIGURE 5-9 NET ANNUAL EROSION/ACCRETION – LITTLEHAMPTON TO RUSTINGTON

The net accretion/erosion rate.

(Influence of beach recycling and replenishment discounted)

FIGURE 5-10 NET ANNUAL EROSION/ACCRETION –RUSTINGTON TO FERRING

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

FIGURE 5-11 NET ANNUAL EROSION / ACCRETION - WORTHING

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

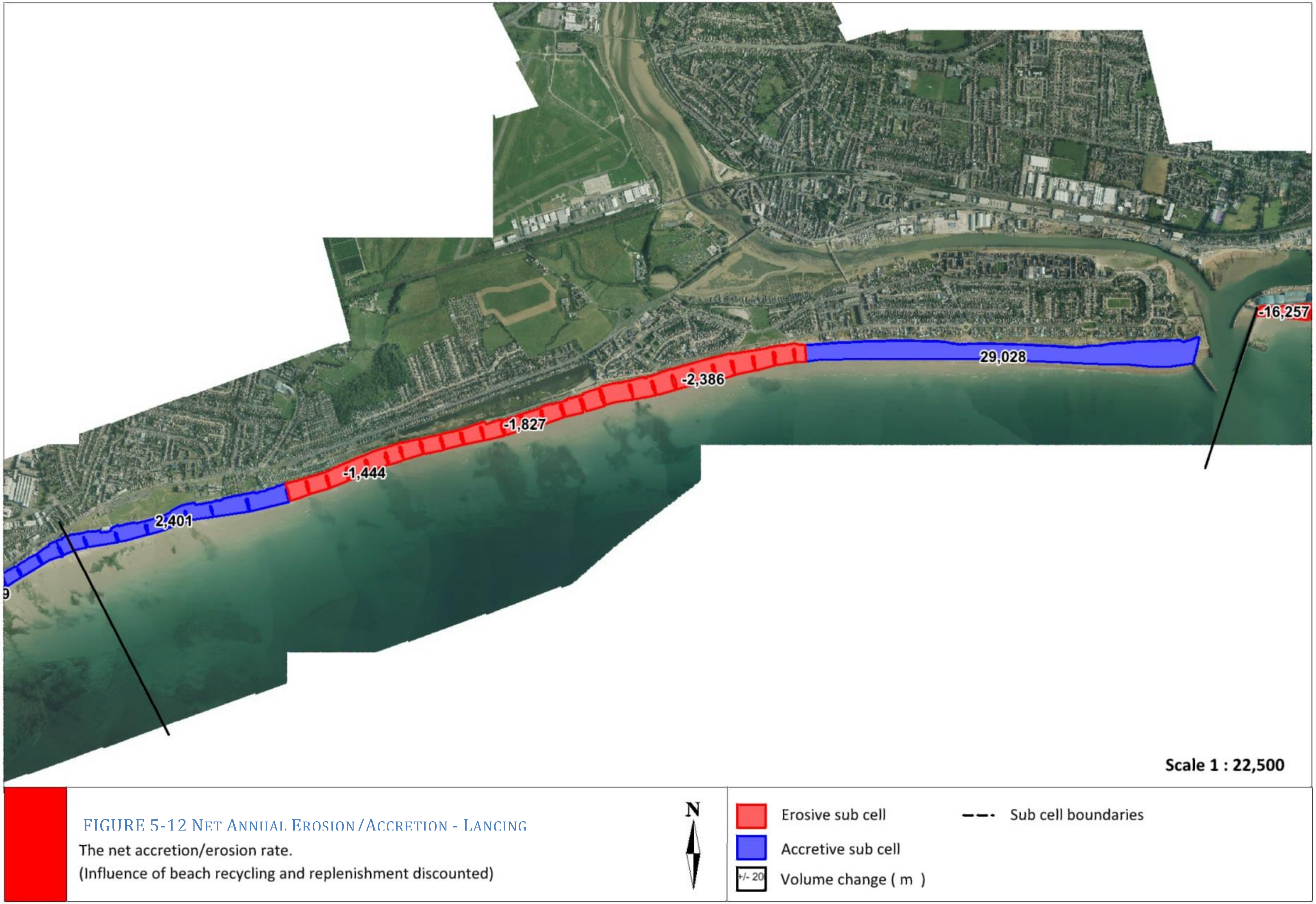


FIGURE 5-12 NET ANNUAL EROSION/ACCRETION - LANCING

The net accretion/erosion rate.

(Influence of beach recycling and replenishment discounted)

FIGURE 5-13 NET ANNUAL EROSION/ACCRETION - SOUTHWICK

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell
Accretive sub cell
+/- 20 Volume change (m)
Sub cell boundaries

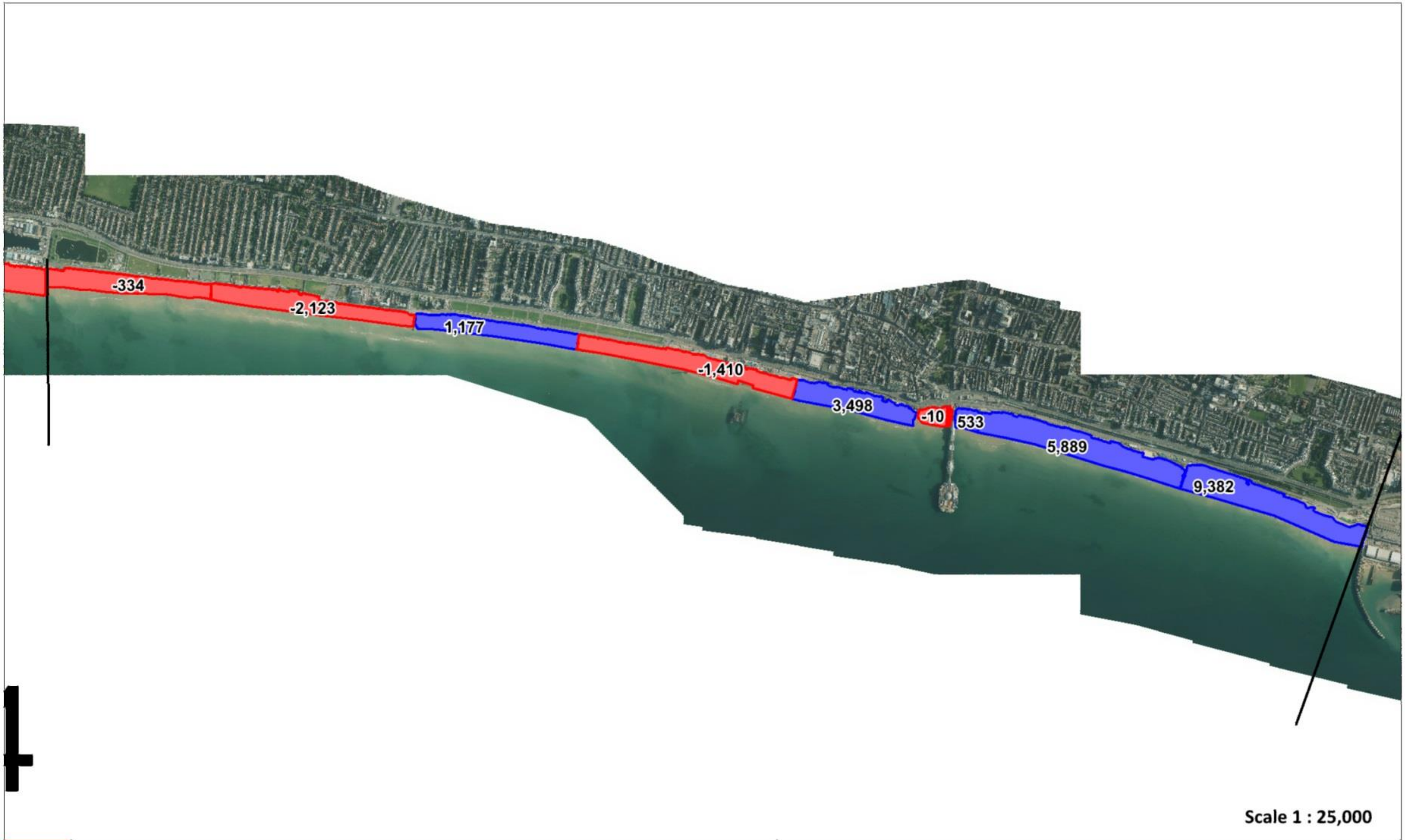


FIGURE 5-14 NET ANNUAL EROSION/ACCRETION - BRIGHTON

The net accretion/erosion rate.
(Influence of beach recycling and replenishment discounted)

N

Erosive sub cell

Accretive sub cell

+/- 20 Volume change (m)

Sub cell boundaries

5-5 UNIT SUMMARY

The previous section discounted the effect of historic beach management operations, but in order to appraise those practices and consider the influence of natural processes it is important to look at the combined impact. This is considered broadly for each unit by calculating the changes in total beach volume.

Assumptions

The Littlehampton to Shoreham sediment budget closed with -40,000m^3 deficit as each unit gained sediment with no viable source to balance the budget. This annual gain of material is supported by the annual bypassing from Shoreham Harbour west to Shoreham Harbour east which looks to take an average of 13,700m^3 out of the Littlehampton to Shoreham cell with no material being replaced. This suggests the beach is gaining sediment from an offshore source with cross shore interaction with the sand foreshore. Lidar, aerial photography and local knowledge suggest a movement of sediment on the foreshore could be contributing to the onshore migration of sediment; further investigation is required to confirm sediment pathways from the subtidal onto the beach.

As the sediment budget had a deficit the whole budget is in the negative which does not allow for sediment transport to be correctly represented and approximately 40,000m^3 was required near the start of the sediment budget to allow it to balance. This sediment was accounted for by offshore input at Rustington of 20,000m^3 and the further 20,000m^3 being distance weighted along the Rustington, Ferring and Worthing units. These values have been distance weighted according to polygon length and provide a realistic sediment budget and are indicative of the sediment transport along this coastline.

The Shoreham Harbour to Brighton Marina sediment budget is much shorter and balanced with only 1,200m^3 unaccounted for.

5-5-1 LITTLEHAMPTON TO RUSTINGTON

This beach is a mixed sand gravel barrier at the western end changing into a fringing beach fronting low level rising ground towards the east and has an extensive sandy foreshore with offshore sand and gravel bars. The extended harbour arm at Littlehampton prevents input of sediment from the West and also provides localized protection against South-Westerly waves. Due to this sheltering effect of the harbour arm, the drift direction is predominantly westerly. Transport rates are relatively low for the study area, ranging between 133m^3 and 20,235m^3

annually (Figure 5-3), with the 133m³ moving from east to west to account for the small gains in the section of beach adjacent to the Littlehampton harbour arm.

The net annual erosion/accretion (Figure 5-9) shows the difference between the beach levels in 2007 and 2017 divided by the number of years. For this unit the two western polygons have gained 1,240m³ and the two eastern polygons have lost 577m³ (Figure 5-9); an overall annual gain of 663m³.

The Total Beach Volume graph, (Figure 5-15) demonstrates that between 2007 and 2013 Rustington had been losing material at a steady rate (approximately 1,500m³ per year), as this volume was interpolated from the two grids, 2007 and 2011. As the years progress the units were surveyed each year and show more varied changes, followed by a gain in 2014 and 2015. A larger loss in 2016 reduced the beach volume to its 2010 position which then gained in 2017. The total volume shows a negligible loss of -956m³ between 2007 and 2017, which differs slightly from the sediment budget (+663m³) because it has considered every dataset since 2007 whereas the sediment budget uses 2007 and 2017 and analyses the trends between only these years. These volumes are deemed negligible and this unit is considered relatively stable.

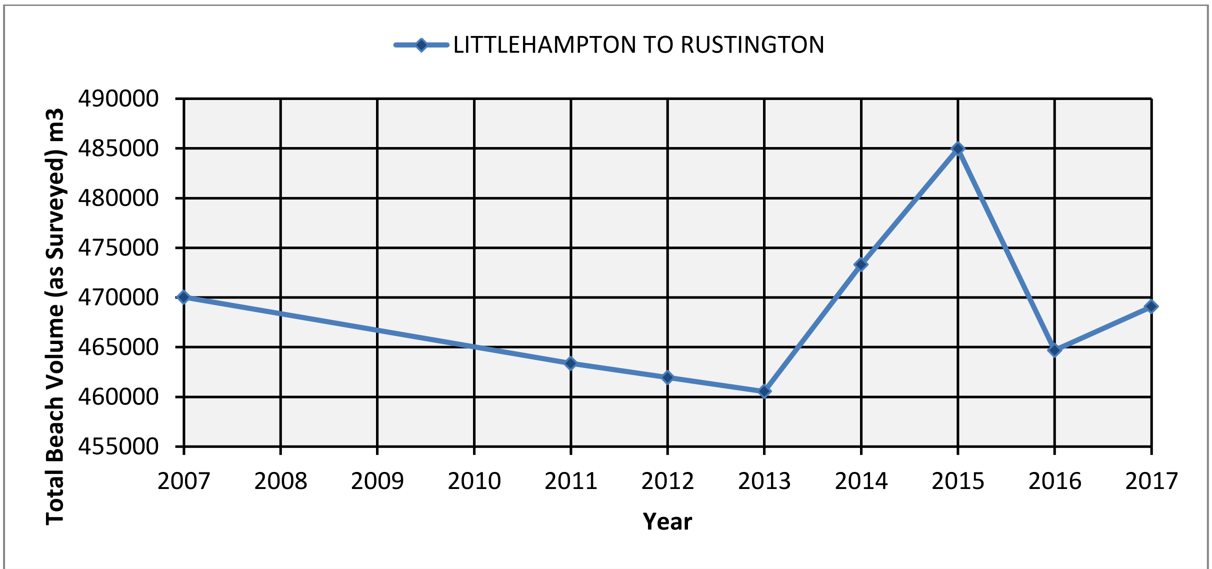


FIGURE 5-15 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN LITTLEHAMPTON TO RUSTINGTON.

5-5-2 RUSTINGTON TO FERRING

This stretch is a gravel beach with a vegetated backshore and sandy foreshore. The predominant drift direction is west to east and the net transport increases eastwards, progressing from 20,235m^3 up to 26,657m^3 (Figure 5-4).

The net annual erosion/accretion (Figure 5-10) illustrates each polygon, bar one, is accretive within the Ferring frontage with a net gain of 4,988m^3 per annum. There is no obvious relationship between the length of the unit or the longitudinal distribution to the accretion rates.

The Total Beach Volume graph shows that, between 2007 and 2012, the beach had been gaining material steadily, approximately 3,000m^3 per year (Figure 5-16). During 2013 and 2014 the beach gained material at a higher rate and has seemingly plateaued since 2015.

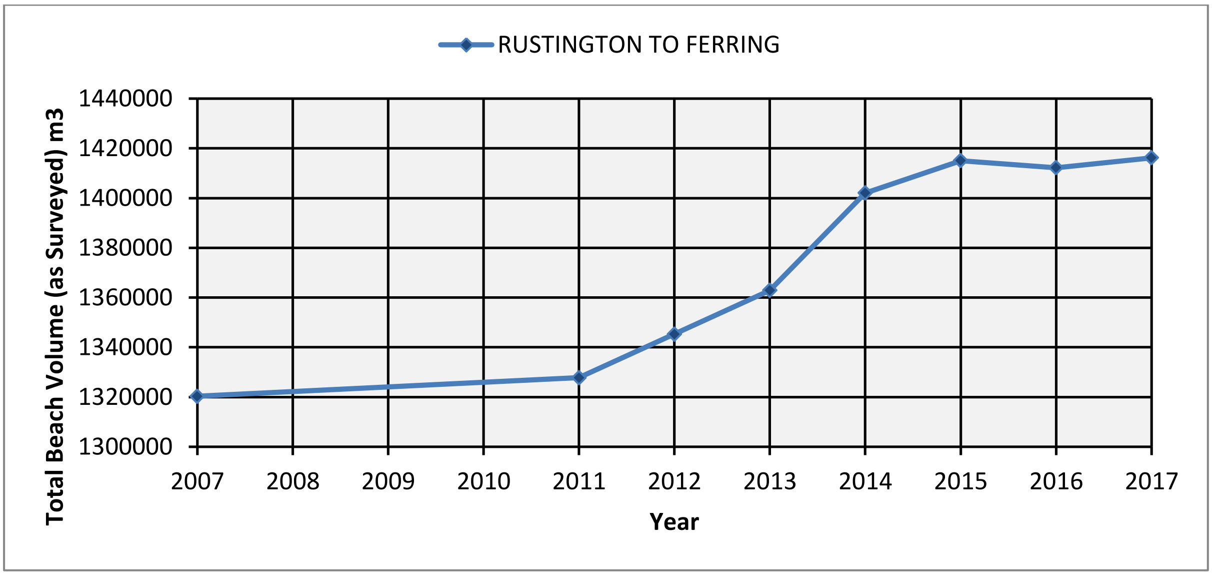


FIGURE 5-16 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN RUSTINGTON TO FERRING.

5-5-3 WORTHING

Worthing unit is a shingle beach with a sandy foreshore. The predominant drift direction is west to east and net sediment transport increases towards the eastern end of the unit. The transport rates are between 25,322m^3 and 27,939m^3 (Figure 5-5).

The net annual erosion/accretion suggests that the unit is typically accretive with the exception of one polygon to the west of the Lido, albeit only losing 464m^3 per year (Figure 5-11).

The Total Beach Volume graph suggests that, between 2007 and 2011, the unit was steadily accreting by around 6,000m^3 a year (Figure 5-17), as this volume was interpolated from the two grids, 2007 and 2011. As the years progress the units were surveyed each years and show more varied changes. During 2012 and 2013 Worthing beach lost approximately 30,000m^3. In 2014 the beach volume accreted by 86,000m^3 despite there being no active recycling or replenishment into this unit. The beach volumes have been a little more varied since 2013 but overall show a gain of 36,000m^3 since 2007.

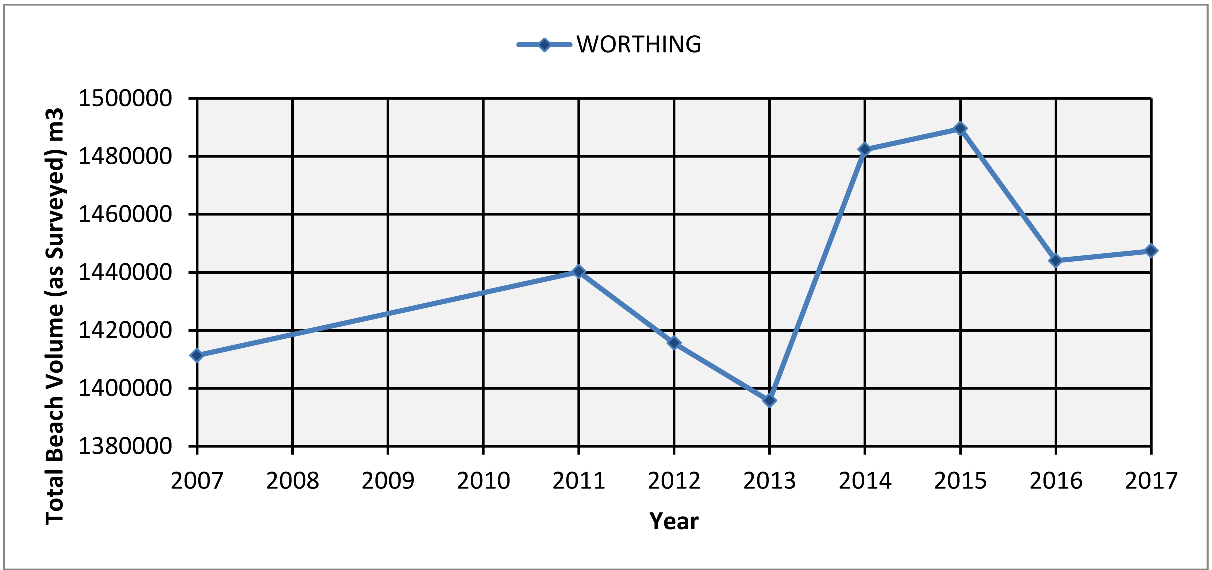


FIGURE 5-17 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN WORTHING.

5-5-4 LANCING

Lancing is a gravel beach with a sandy foreshore. The predominant drift direction is west to east and sediment transport levels through the unit are high, peaking at just less than 30,000m^3 – the highest within the study area (Figure 5-6). Approximately 25,000m^3 is transported into Lancing from Worthing per year and as no material naturally bypasses the harbour arm, which acts as a terminal groyne, the unit continues to gain year or year. The total volume graph displays the As Surveyed beach volumes which does not discount the ~13,700m^3 bypassed annually around Shoreham Harbour.

The net annual erosion/accretion shows a clear dichotomy between the erosive western half of the unit and the accretive east. The split between erosion and accretion is positioned to the point where the coastline changes direction. West of this position the beach loses 5,500m^3 of sediment a year whilst to the east there is a sediment gain of 29,000m^3(Figure 5-12).

The Total Beach Volume graph (Figure 5-18) shows that between 2007 and 2011 the beach was gaining material by approximately 2,500m^3 per year, as this volume was interpolated from the two grids, 2007 and 2011. As the years progress the units were surveyed each years and show more varied changes. In 2012 there was a large drop in beach volume by 48,000m^3. The beach has since accreted a further 130,000m^3 to 2017.

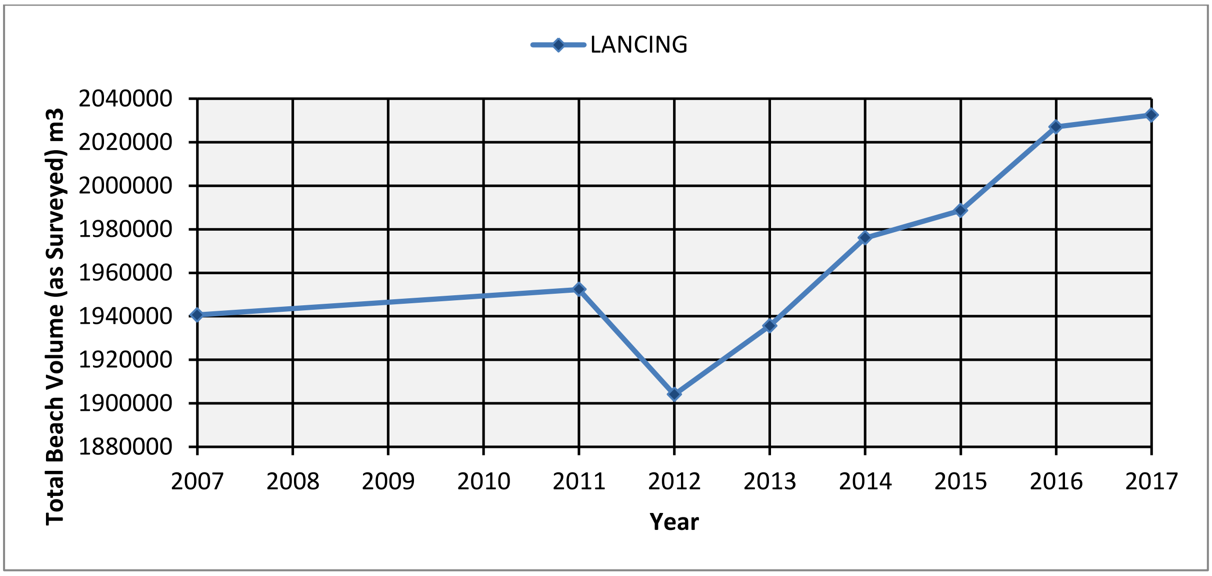


FIGURE 5-18 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN LANCING.

5-5-5 SOUTHWICK

Southwick is a gravel beach with a sandy foreshore. The predominant drift direction is west to east. Two harbour arms at the western boundary of the unit act as a terminal groyne, preventing any movement of shingle into Southwick. There is a high transport rate of 16,257m^3 out of the polygon adjacent to the harbour because of the scour and lack of natural sediment input caused by the terminal groyne effect (Figure 5-7). The sediment transport rate reduces slightly to between 15,000m^3 and 16,000m^3.

The net annual erosion/accretion (Figure 5-13) suggests the western most polygon is losing the highest volume of material at 16,257m^3 per year. This is due to the position of the sea wall, which is fixed seaward of the point required to allow beach material to be accommodated. The losses in the adjacent polygon are demonstrating small gains of 500-700m^3 as they are directly benefitting from the replenishment up drift.

The Total Beach Volume graph indicates that between 2007 and 2011 the beach was steadily gaining c.2,500m^3 per year (Figure 5-19), as this volume was interpolated from the two grids, 2007 and 2011. As the years progress the units were surveyed each years and show more varied changes. In 2012 there was a large loss of 22,500m^3 followed by two years of gains and a fluctuating beach volume. This total beach volume graph represents the As Surveyed volumes and does not discount the annual 13,700m^3 deposited in the Southwick frontage from Lancing. Between 2007 and 2017 the total volume increased by only 7,000m^3, with 170,000m^3 of material being bypassed to this unit during this time.

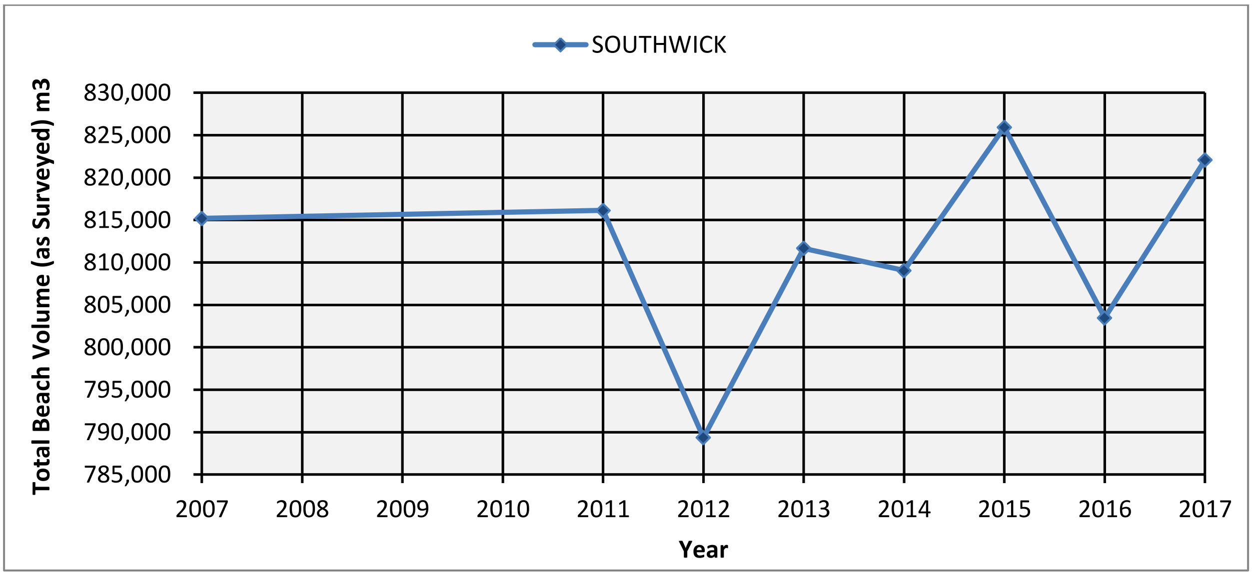


FIGURE 5-19 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN SOUTHWICK.

5-5-6 BRIGHTON

Brighton is a gravel beach which becomes increasingly coarse towards the east. The predominant drift direction is west to east. Net sediment transport averages around 14,000m³ between the western unit boundary and the Pier (Figure 5-8). East of the pier this value decreases exponentially as material is deposited in front of the Brighton Marina arm. No material bypasses the Marina.

The net annual erosion/accretion (Figure 5-14) indicates there are four erosive polygons, two bordering the Southwick unit (losing a combined volume of 2,500m³ per annum). Generally, there is a divide between the west and the east of Brighton unit, with the west showing signs of beach loss and the east gaining; overall there is a net gain.

The Total Beach Volume graph shows that Brighton is gaining material (Figure 5-20). Between 2007 and 2011 the unit was steadily gaining approximately 11,000m³ per year, as this volume was interpolated from the two grids, 2007 and 2011. As the years progress the units were surveyed each years and show more varied changes. There was a 20,000m³ loss in 2012 but otherwise every year has gained.

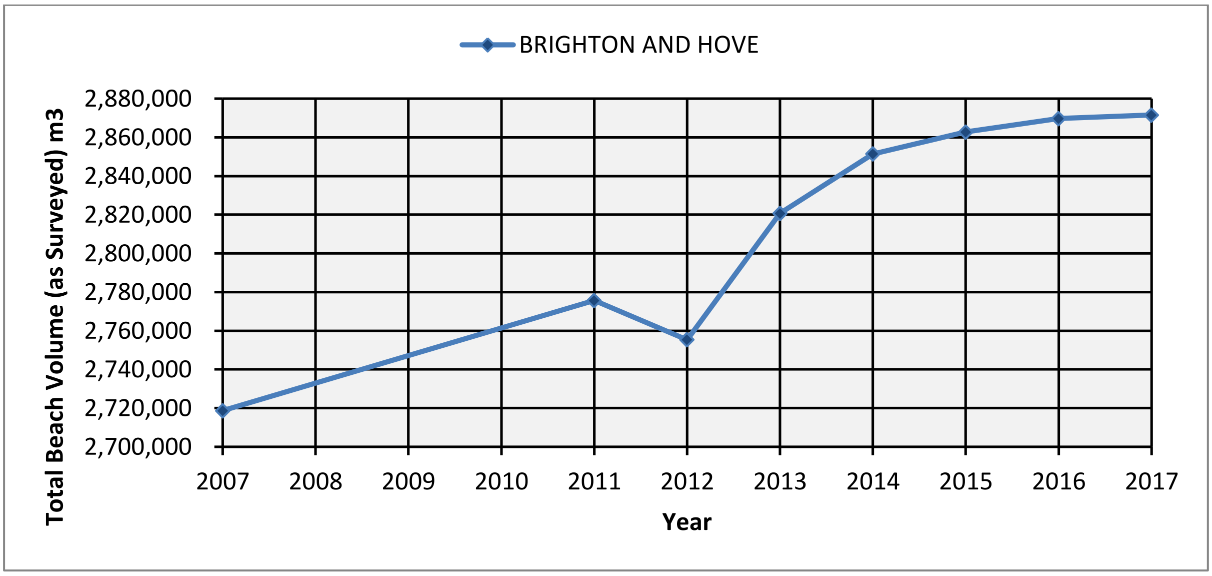


FIGURE 5-20 TOTAL BEACH VOLUME CHANGE BETWEEN 2007 – 2017 IN BRIGHTON.

6 RISK ANALYSIS

6-1 DEFENCE SECTIONS

In order to perform the risk analysis the coastline was split into representative defence sections based upon sea defence, beach and foreshore characteristics (Figure 6-1-1). Details on the defence type, elevation and geometry, foreshore levels and the calculations performed for each defence section is provided in Appendix G.

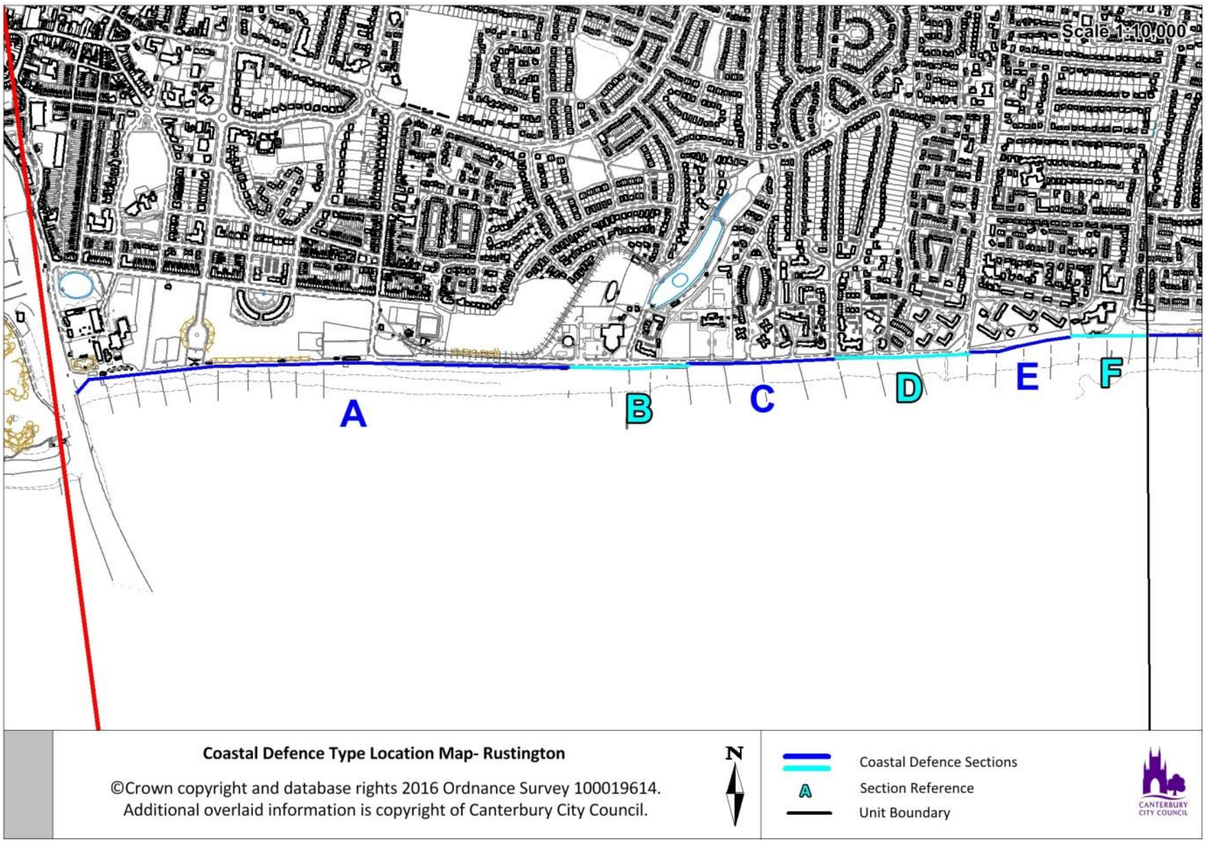


FIGURE 6-1-1 EXAMPLE OF DEFENCE SECTIONS FOR RUSTINGTON

6-2 METHODOLOGY

6-2-1 OVERTOPPING

The primary short-term threat considered in this report is excessive overtopping of the shingle beaches and structures, causing flooding and damage to property and infrastructure.

Overtopping can pose a risk to pedestrians, vehicles, trains and structures behind the defence through discharge flows and flying shingle. The EurOtop Manual (Pullen et al., 2007) defines the consequences of overtopping into four general categories;

a) *Direct hazard of injury or death to people immediately behind the defence.*
b) *Damage to property, operation and/or infrastructure in the area defended, including loss of economic, environmental or other resource, or disruption to an economic activity or process*
c) *Damage to defence structure(s), either short-term or longer-term, with the possibility of breaching and flooding.*
d) *Localised flooding from overtopping discharge*

Shingle beaches are very efficient at dissipating wave energy (Figure 6-2-1). To calculate overtopping rates under different scenarios a methodology was developed and applied consistently to the whole frontage. This is summarised in Figure 6-2-2 and described in the following text.

FIGURE 6-2-1 DISSIPATION OF WAVE ENERGY ON A SHINGLE BEACH (KINGSDOWN, 2009)

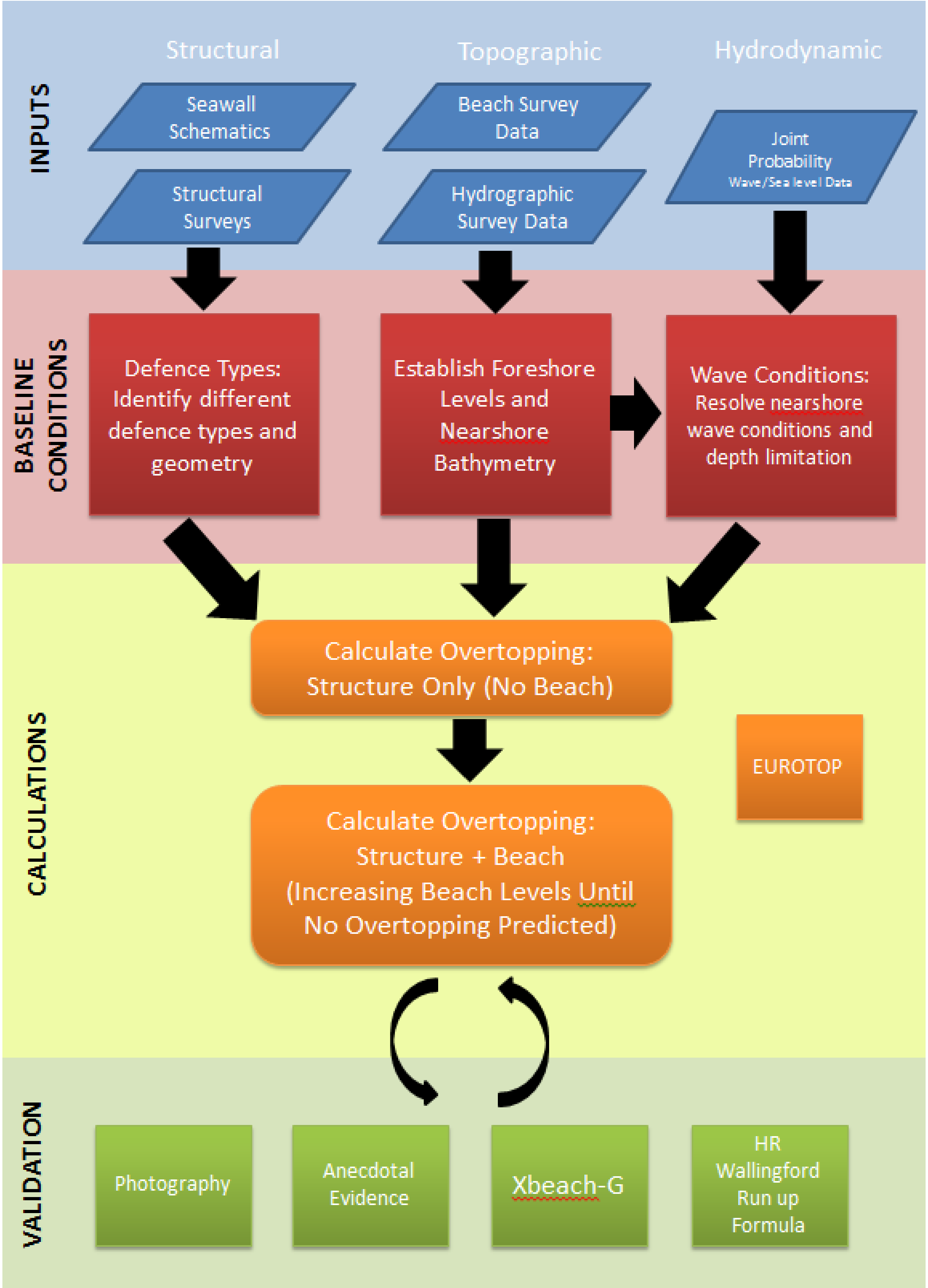


FIGURE 6-2-2 SUMMARY OF OVERTOPPING METHODOLOGY DEVELOPED FOR THIS REPORT

INPUTS

Structural geometry was obtained through seawall schematics/as built drawings where available. These not only provide the crest height of structures but also the hidden portion of the defence and toe levels obscured by current beach levels. In areas where this information was not available the analysis relied on structure surveys of the visible defence carried out as part of the Regional Coastal Monitoring Programme. When the latter provided insufficient detail it was supplemented with LiDAR data.

Beach survey data provided current beach levels and geometry in addition to historical variations dating back to 1999. Where this provided insufficient information on beach toe levels, foreshore heights and the approach to the beach it was supplemented with bathymetric survey data.

Hydrodynamic conditions were defined by the outputs of the joint probability study (Mason, 2014) and provided nearshore conditions for return probabilities from 1 to 200 years.

BASELINE CONDITIONS

Structural geometry and foreshore levels were used to break down each management unit into defence sections (see Section 6-1). These then formed the basis for each different set of overtopping calculations. In order to calculate the worst set of conditions for each set of joint probability values it was necessary to account for the effects of depth limitation and define wave conditions at the toe of the structure/beach (Figure 6-2-3).

All management units in the study area have depth limited waves under the higher return period events. To calculate the depth limited spectral significant wave height at the structure/beach toe the results from a simple 1D energy decay model (Van der Meer, 1990) are used, in which the influence of wave breaking is included. The model converts deep water wave steepness, local water depth and the slope of the foreshore into a breaker index (Pullen et al., 2007). The latter defines the reduction in significant wave height.

Results produce a wave height limited to between 50-60% of the water depth; precise figures for each defence section are included in the results spreadsheets in Appendix G.

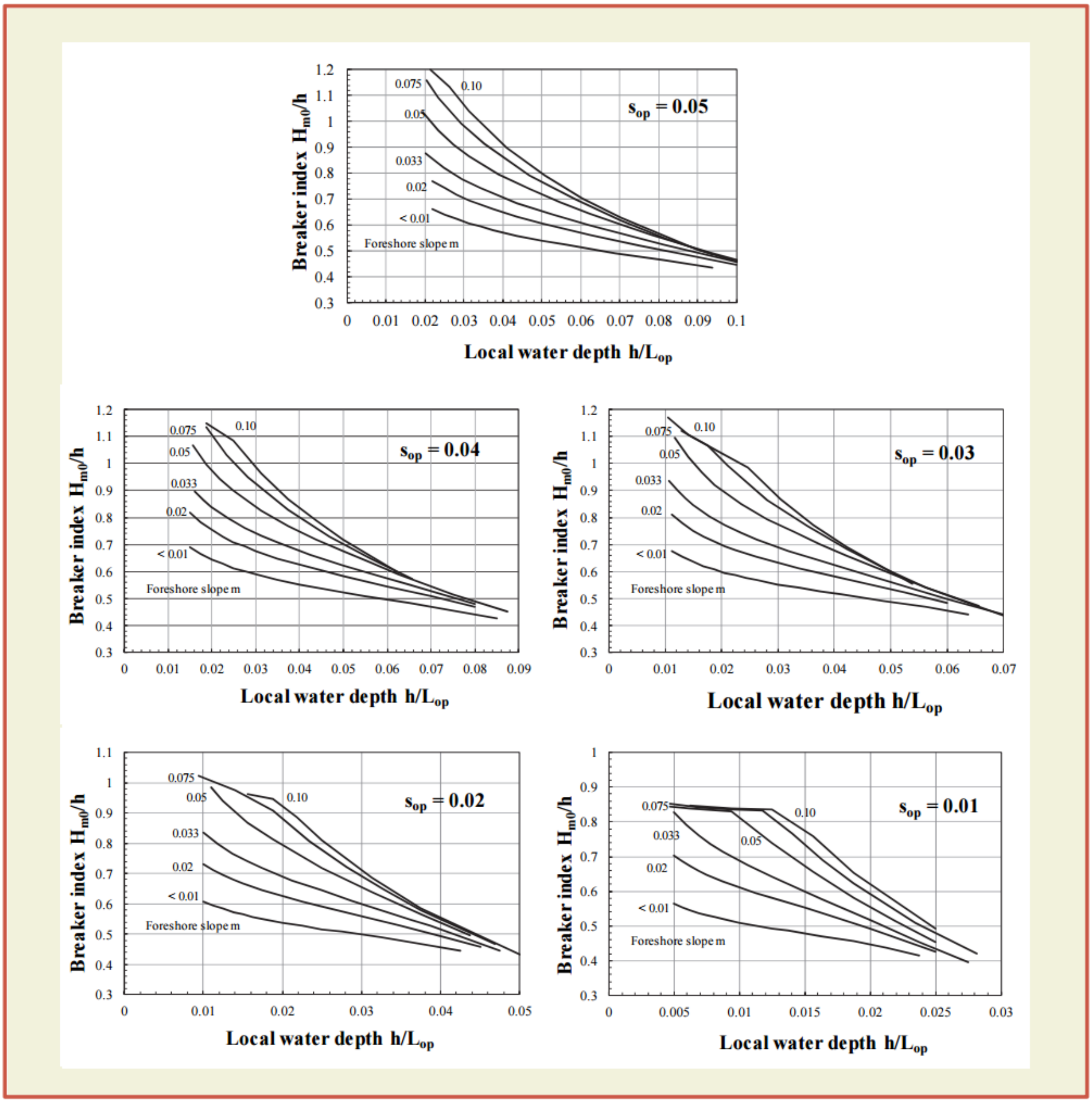


FIGURE 6-2-3 CALCULATION OF DEPTH LIMITATION USING THE BREAKER INDEX (PULLEN ET AL, 2007)

CALCULATIONS

For most calculations the EUROTOP research was used (Pullen et al., 2007), based on significant previous research and physical model testing it provides a tool for calculating overtopping at a variety of seawall and structure types.

Initial calculations were run for each defence type without a beach present (Figure 6-2-4); this provided a worst case scenario for each section. As there is more confidence in the overtopping results for standalone structures it also provided a baseline for further calculations.

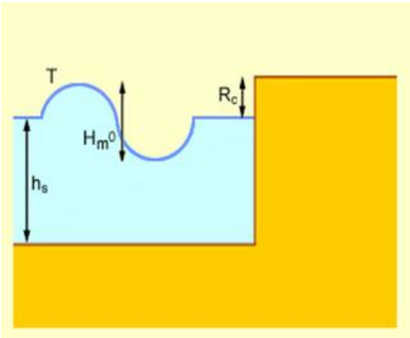


FIGURE 6-2-4 EUROTOP - CALCULATION OF OVERTOPPING AT A SIMPLE VERTICAL SEAWALL

The reason that there is more confidence in predicted results for standalone structures is that the geometry is simple and fixed. They are also well suited to Physical model testing with limited scaling effects; this also largely applies to more complex structures and rock revetments. Introducing a shingle beach to the defence geometry creates a higher level of uncertainty owing to the very limited number of laboratory or field tests.

When calculating wave run-up on shingle beaches there are a number of factors that will affect the result and are also subject to change in the short term. These include beach volume, beach shape and beach composition. The first two can be constrained by locally known variability from the coastal monitoring programme but beach composition, including grain size and grading, permeability and roughness factors can only be approximated, especially as they change both spatially (within a management unit) and temporally (over various time scales).

In order to improve on current methods of calculating beach run-up a sub-project to this report was commissioned, *Wave run-up on shingle beaches: a new method* (HRW, 2014). The report contains a comparison between a set of measured run-up data taken at Worthing beach and several established formula for predicting run-up. These include some of the methods available in EurOtop, Figure 6-2-5 illustrates the results from one of the more simplistic approaches.

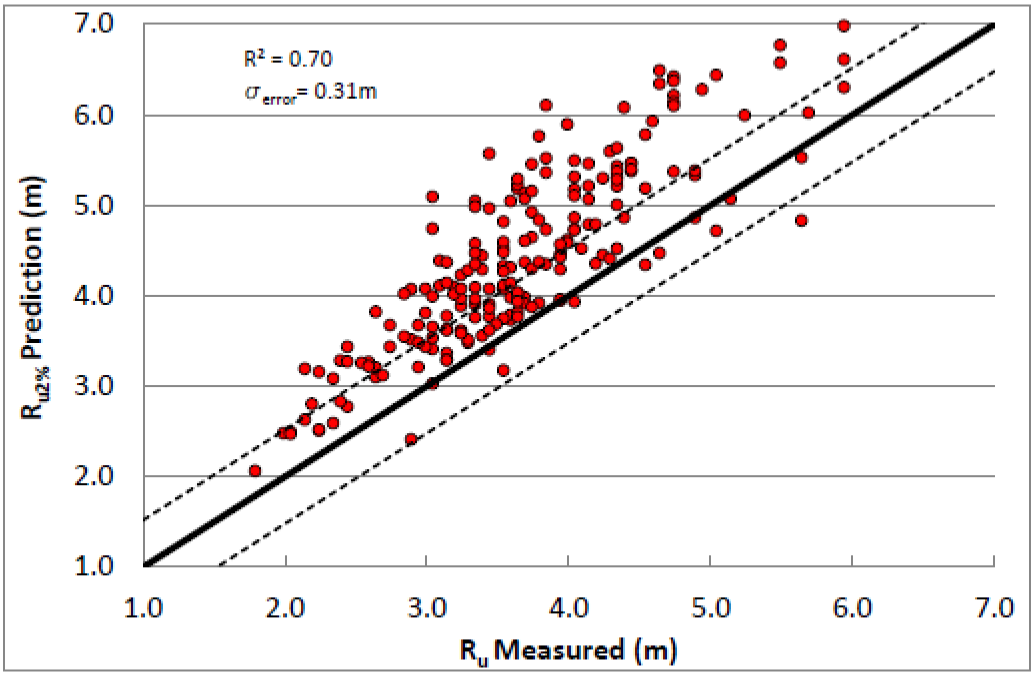


FIGURE 6-2-5 SIMPLISTIC EUROTOP METHOD VS ACTUAL MEASURED DATA AT WORTHING (HRW, 2014)

The main output of the report was an improved formula for calculating run-up on shingle beaches. The formula uses a representation of the spectral wave data, and in particular takes good account of the swell component, producing a much better fit to measured data at Worthing and smaller samples taken elsewhere on shingle beaches in the Southeast.

For this study the new formula was not used for the bulk of the calculations but was used as a validation tool to sense check the results from EurOtop, for example overtopping can only start once run-up has reached the beach crest level. There are two main reasons for this;

a) *The new formula uses spectral wave data and although recorded spectral data is available from the local wave buoys there is no way to predict the swell component of larger storms and their return periods.*

b) *There is no simple way to incorporate the new run-up formula into the EUROTOP calculation tools when assessing overtopping for a combined beach and structure.*

There are plans to update EUROTOP to include the formula; there is also on-going research at HR Wallingford to assess the effects of bi-modal seas and overtopping of shingle beaches and structures. When this is complete it may be possible to improve on the results of this study, but the results presented are produced using current EUROTOP methodology, however the improved formula is used to help validate results.

For each defence section the structure only results were used as a starting point, a small beach was then introduced to the geometry and overtopping rates calculated (Figure 6-2-6). The size of the beach was then steadily increased until the point was reached where no overtopping was predicted. In order to make the results more comparable with surveyed beach levels and design levels each beach size was converted to a representative cross sectional area (CSA).

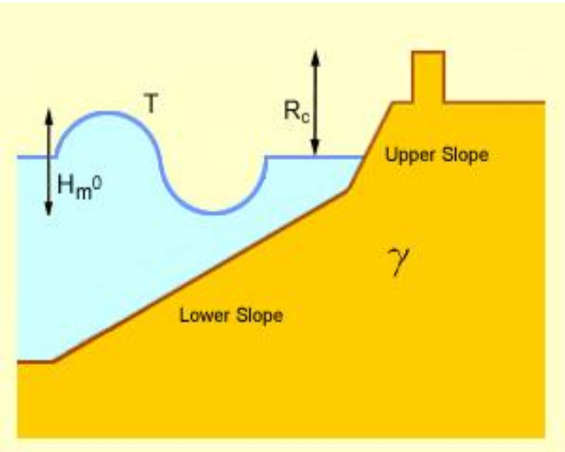


FIGURE 6-2-6 EUROTOP- CALCULATION USING MORE COMPLEX STRUCTURES

In order to calculate the influence of wave return walls with beaches it was necessary to perform an adjustment outside of EurOtop. The general principle applied within EurOtop is that a wall with a large freeboard has the biggest reduction in wave overtopping as the wave has room to be channelled by the wave return. As water levels increase the effect of the wave return declines until it reaches a point where it has no effect at all in reducing overtopping. The same principle applies to shingle beaches, where crest levels towards the top of the wall diminish the effect. This is not accounted for in EUROTOP so the equations were adapted and applied as an adjustment to the overtopping figures. The full methodology is described in Appendix G.

While the authors concede that the EUROTOP methodology used for this study has a propensity to over predict run-up on shingle beaches, and therefore overtopping, it effectively calculates the maximum run-up/overtopping for a given set of input conditions. The variability introduced by not fully accounting for inputs such as swell conditions means that the actual values may be lower, but rarely higher. This is important when establishing critical defence levels, and also builds in a factor of safety to the final results; hence we have carried out the validation.

VALIDATION

Given the potential uncertainty in overtopping results it was important to validate the results, this was done with four methods.

1. Photographic evidence of large overtopping events and retrospective comparison with predicted overtopping (e.g. Figure 6-2-7).

FIGURE 6-2-7 WAVE OVERTOPPING, BRIGHTON (FEBRUARY, 2016)

2. Anecdotal evidence in the form of information that is not well documented or photographed. The prime example of this is shingle on the promenade, which is indicative of small scale overtopping (e.g. Figure 6-2-8). Where management authorities have to periodically clear this it is evident that the defence is subject to minor overtopping on a regular basis. Results can be queried to ensure these events are predicted.

FIGURE 6-2-8 EVIDENCE OF OVERTOPPING ON TO THE PROMENADE, LITTLEHAMPTON (2014)

3. XBeach-G is a software tool developed in collaboration between Plymouth University and Deltares (Masselink et al, 2014). It simulates storm impacts on gravel beaches and computes wave-by-wave flow and surface elevations over the duration of a storm. Sample data along the study area was run in XBeach-G to check the results were comparable (Figure 6-2-9).

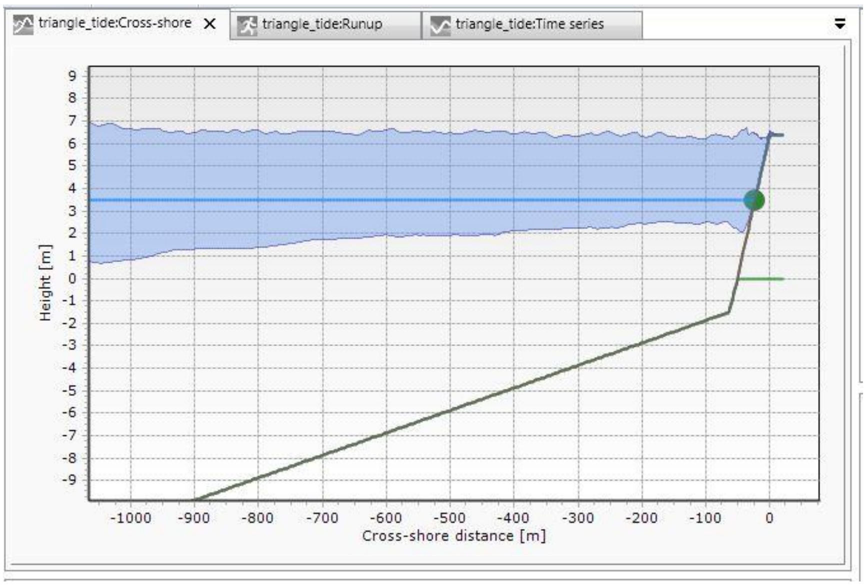


FIGURE 6-2-9 XBEACH-G SAMPLE SCREENSHOT

4. The improved formula presented in Wave run-up on shingle beaches: a new method (HRW, 2014, see Figure 6-2-10) was used in areas that were prone to green water overtopping (No structure and run-up exceeds crest). By running calculations for a number of swell components results could be verified as reasonable and ensure that an underestimate had not been made.

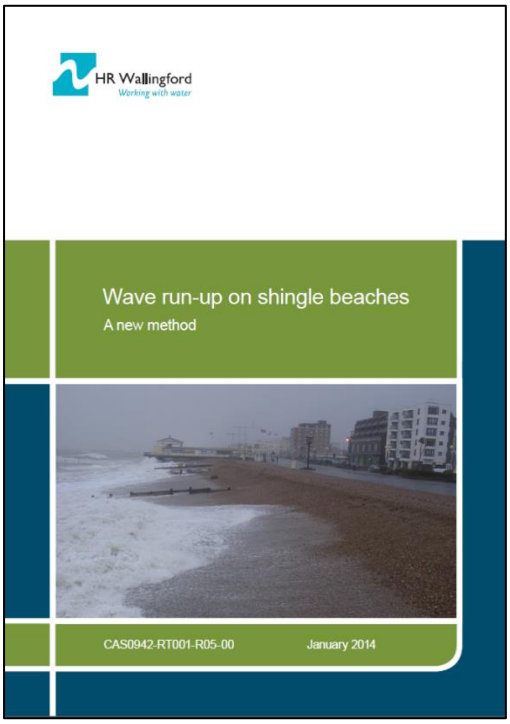


FIGURE 6-2-10 SUB-PROJECT RESEARCH AND DEVELOPMENT OF IMPROVED RUN-UP FORMULA

6-2-2 SEAWALL FAILURE

Coastal defences in the Southeast most commonly consist of a beach and structure combination. These work in unison with the beach absorbing wave energy, breaking waves and protecting the sea wall from direct wave attack. The wall acts to further reduce the risk of overtopping from waves that run up past the crest and present a significant barrier to overtopping and erosion should the beach levels drop to lower levels. Consequently these elements should not be considered in isolation, but as two parts of the same defence with each one playing a critical role.

As beach levels lower due to erosion, draw down in a storm, or failure of groynes that act as controlling structures the seawall becomes increasingly exposed to direct wave attack. In addition to a probable increase in overtopping rates, this significantly increases the risk of seawall failure.

FIGURE 6-2-11 DILAPIDATED GROYNES, LOW BEACH AND SEAWALL FAILURE AT KINGSDOWN (2013)

As beach levels continue to drop there is an additional threat of undermining of the seawall foundations. This can cause the structure to collapse and/or a draining of the fill material from behind the seawall that reduces the structural integrity (Figures 6-2-11 and 6-2-12). A beach also provides a lot of support and weighting in front of the structure, without which toppling or sliding of seawall sections can occur (Figure 6-2-13).

Typically, before beach levels get low enough to pose a credible threat to the structure the standard of protection has already become sub-standard due to the increased likelihood and severity of overtopping. There are instances where the structure itself provides a sufficient barrier to overtopping, but often in these cases a beach is required to be maintained in order to protect the structure and prevent undermining.

FIGURE 6-2-12 EXAMPLES OF UNDERMINING AT TANKERTON (LEFT) AND RECULVER (RIGHT) (BOTH PHOTOS 1999)

Calculating failure probabilities for all stretches of structures along the study frontage is outside the scope of this report. Additionally, the conditions of seawalls are often unknown especially if covered by beach for many years. The report does however highlight areas where the loss of beach would result in the potential for undermining and/or increased exposure to wave attack that may result in a significantly increased risk of failure.

For coastal management authorities should undertake regular asset condition inspections in order to assess the need for any maintenance. Historically these may have been picked up by NFCDD inspections. It is anticipated that this will shortly be replaced by AIMS, but in the interim each coast protection authority should conduct their own regular coastal asset inspections.

FIGURE 6-2-13 FAILURE OF A SEAWALL AT ALL HALLOWS DUE TO SLIDING/TOPPLING OF DEFENCE SECTIONS (2015)

Two types of seawall failure are considered in this method; undermining and structural failure (breach or partial breach). For seawalls in good condition undermining is assumed to be the critical failure mechanism, and for seawalls in bad condition (where there is a risk that wave attack will cause failure) structural failure is assumed to be the critical failure mechanism. These calculations are dependent upon the type, construction and condition (where known) of the sea defences (all known defence schematics are provided in Appendix F).

For undermining calculations a beach level was calculated that prevents the defence foundations from being exposed, allowing for a 1:10 slope (due to draw down during a storm event) and a 50cm depth of scour (Figure 6-2-14). The full methodology is provided in Appendix G.

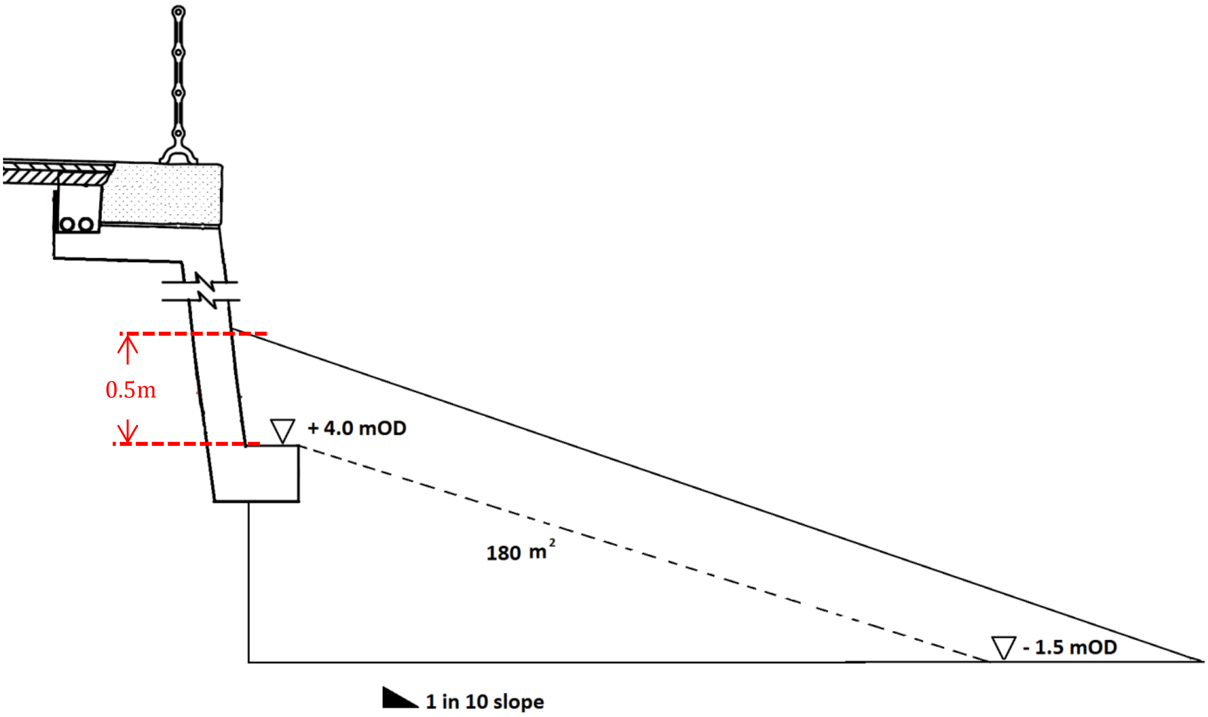


FIGURE 6-2-14 CRITICAL BEACH LEVEL TO PREVENT UNDERMINING OF THE DEFENCE FOUNDATIONS INCLUDING A 50CM ALLOWANCE FOR SCOUR

For structural failure a beach cross section is calculated that prevents critical overtopping (and wave attack) of the defence structure, using the Eurotop allowable overtopping limits (see Appendix C).

6-2-3 FLOODING & BREACHING

Flooding can occur through excessive overtopping, seawall failure or breaching of barrier beaches. All of these scenarios can result in flooding when the hinterland is below the extreme sea level or defence height.

In order to calculate the properties at risk from a 1:200 year event (4.5mOD) a planar still water level flood map was created using LiDAR data (most recent dataset, 2015) and combined with the Ordnance Survey's AddressBase property layer (Figure 6-2-15). There are 2 larger flood basins at Rustington and Worthing and a smaller basin at Ferring.

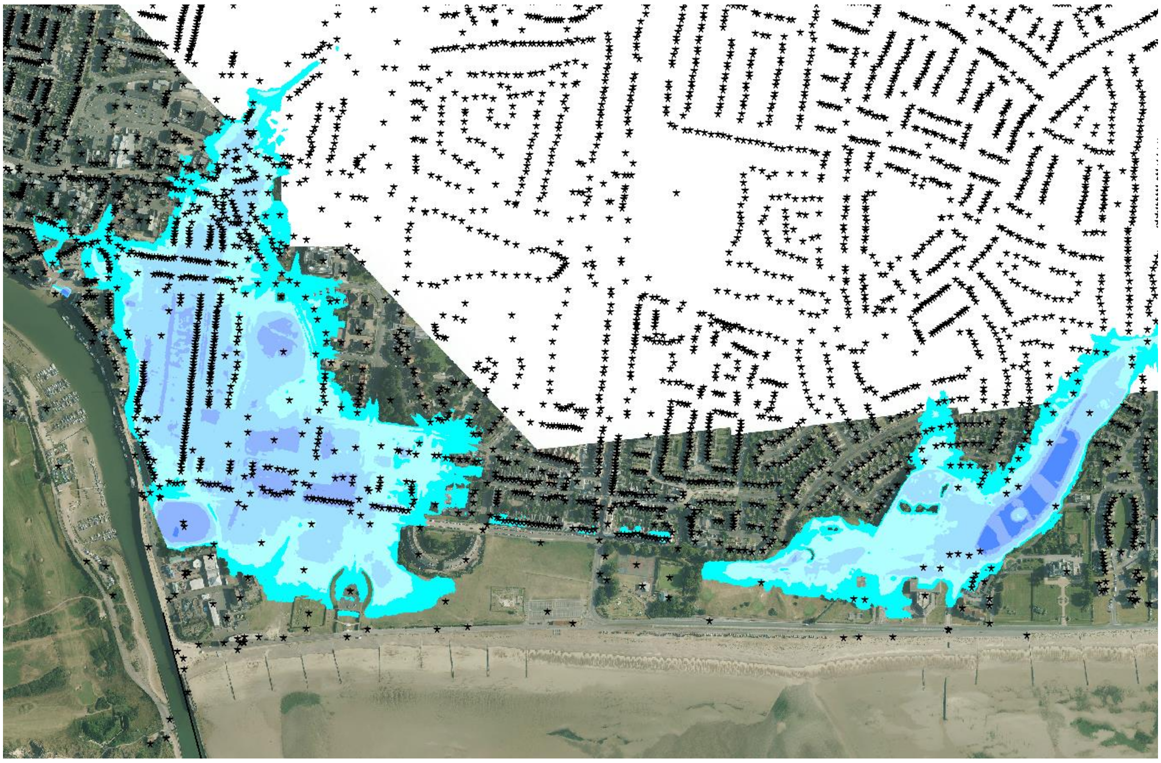


FIGURE 6-2-15 EXAMPLE OF PROPERTIES (STARS) WITHIN THE 1:200 YEAR EXTREME WATER LEVEL PLANAR FLOODPLAIN (RUSTINGTON)

A database of at-risk properties was created with information including, property type (Detached, Semi-detached, Terrace, Flat etc.), council task banding, postcode and street address. This detailed information is then combined with the ZOOPLA house price database to produce cost estimates for those properties at risk of flooding (Table 6-1).

TABLE 6-1 ESTIMATED PROPERTY DAMAGE COSTS

PLACE	PROPERTIES AT RISK	APPROX. VALUE (£K)
LITTLEHAMPTON TO RUSTINGTON	1,312	304,761
RUSTINGTON TO FERRING	13	4,505
GORING	222	72,269
WORTHING & LANCING	1,330	357,266

In total this equates to a theoretical value of over £730 million of property that is reliant on the sea defences not breaching on a large scale along this frontage. There are several important caveats; firstly that the planar still water level floodplain does not account for flood pathways, and secondly that above ground properties have not been removed from the total count. In reality, the most likely flooding events would result in only a partial inundation of the flood plain, however modelling numerous individual breach and overtopping scenarios is outside the scope of this report.

6-3 OVERTOPPING OUTPUT

In order to visualise the results for each defence section they are presented on a chart (Figure 6-3-1) which compares the predicted overtopping rate with the size of the beach cross sectional area (CSA). This shows the decrease in overtopping for each of the return period conditions (1 to 200 years) as the size of the beach increases. For sections where a rock revetment is present, a single overtopping calculation is performed for overtopping over the revetment.

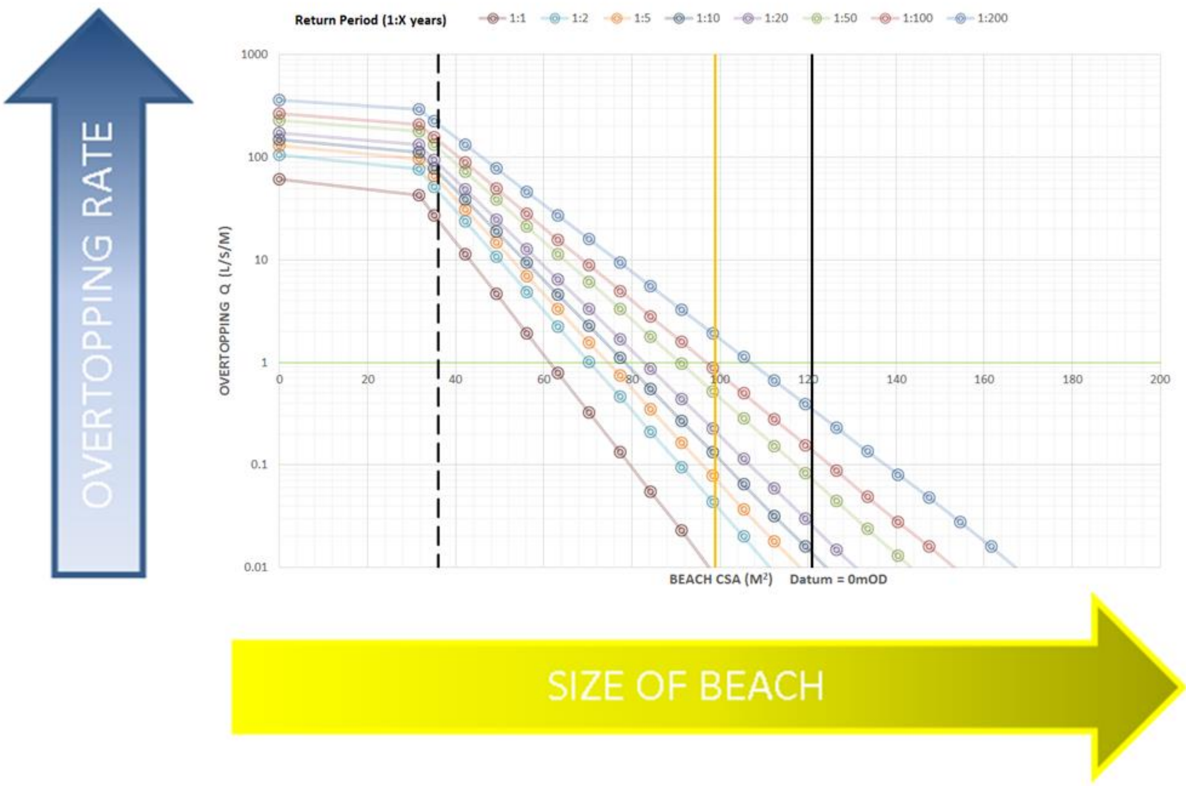


FIGURE 6-3-1 EXAMPLE OF OVERTOPPING RESULTS CHART

From the chart it is possible to read off a predicted overtopping rate for a particular beach size under different conditions. The jump from zero CSA to the next point reflects the fact that CSA is calculated above a datum (normally the beach toe level), but in reality some of that area is composed of foreshore and lower structure geometry, however to aid clarity calculations solely conducted on structures (no beach) are plotted at zero.

Three vertical lines are plotted on the chart to add context to the results.

Dashed black - the lowest CSA values recorded for the smallest beach profile (2003-2015)

Solid black – the highest CSA values recorded for the largest beach profile (2003 – 2015)

Amber line - the current (summer 2015) lowest CSA value recorded for any profile in that defence section.

All three of these lines could represent different profiles within the section. Details for each profile can be found in Chapter 7.

The majority of these frontages have a combination of beach and seawall and the overtopping calculations consider them both; presenting the results according to the actual structural configuration seen on site.

Where the beach is the only forward defence (i.e. no hard structure or rock armour) the calculations are based on the beach only and an additional line is plotted (red dashed), showing the minimum CSA at which the modelled crest height can be maintained at a 1:7 slope. The calculations for cross-sectional areas less than this threshold value are based upon a reduced crest height (Figure 6-3-2). This threshold CSA value is denoted by a dashed red line on the graphs.

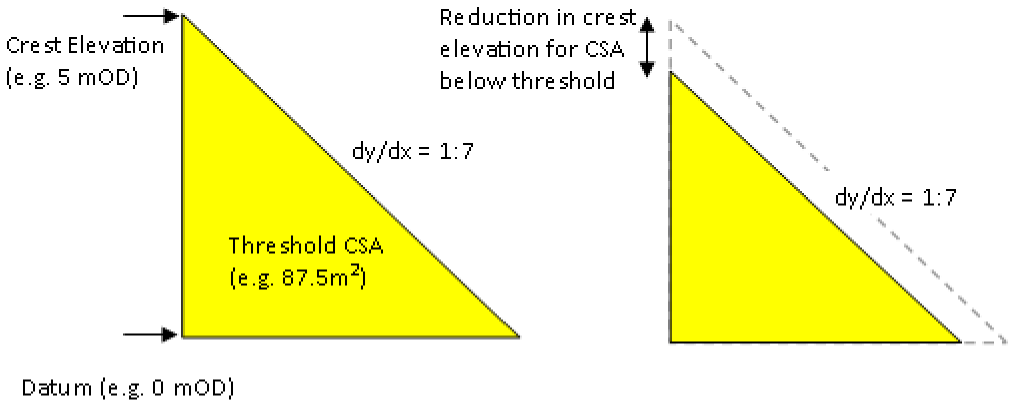


FIGURE 6-3-2 REDUCTION IN CREST HEIGHT FOR PROFILES BELOW A THRESHOLD CSA

Where defence structures have both a front wall and a rear wall results are presented for both components of the defence. The notation is a 2 after the section name for the rear wall, for example Rustington A describes the results for the front wall, and Rustington A2 describes the results for the rear wall. An example results graph is shown in Figure 6-3-3; full results and details of the input conditions are provided for each set of calculations within appendix G. The relationship to the defence standard of protection is shown in Chapter 7, and the implications of the results are discussed in Chapter 8.

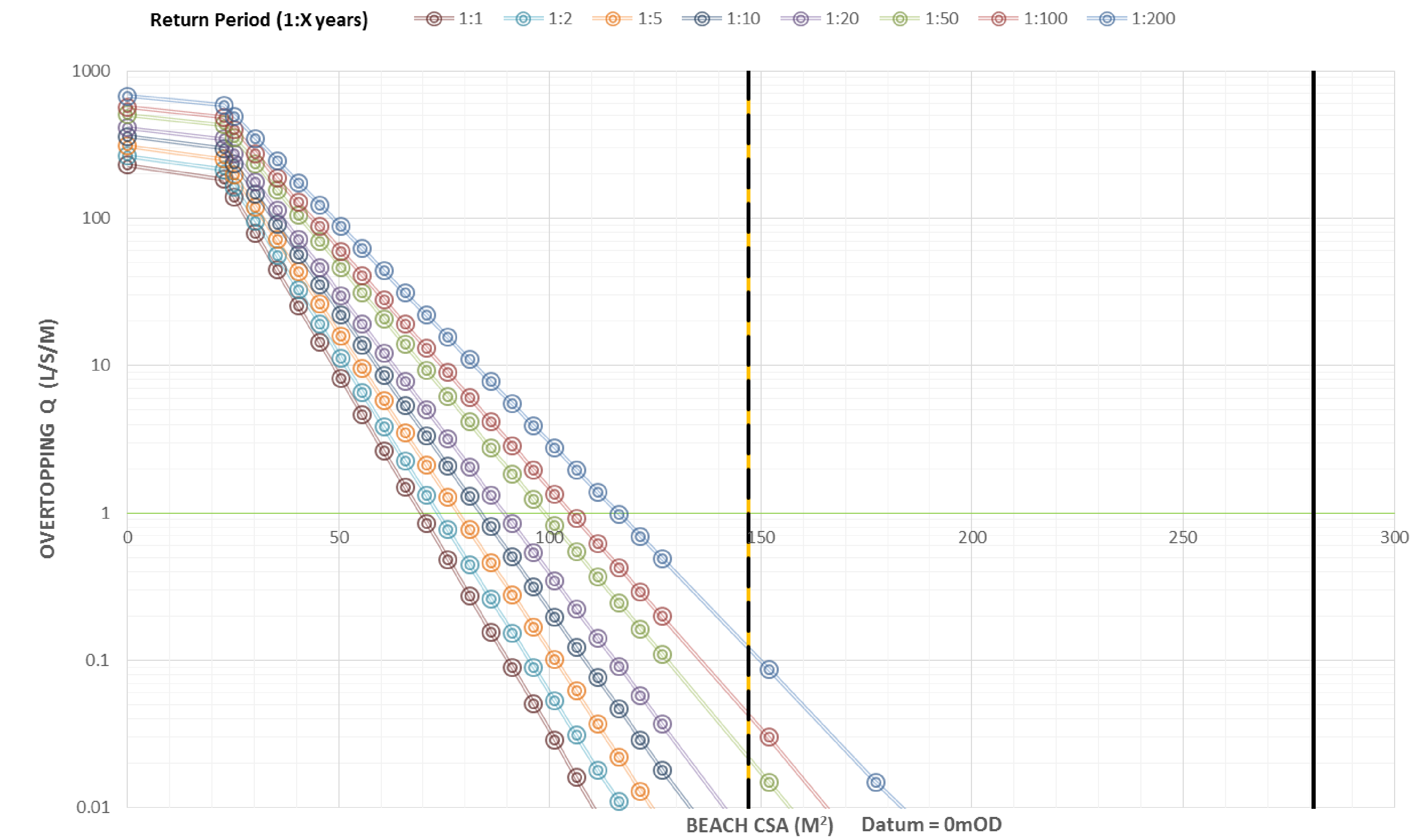


FIGURE 6-3-3 OVERTOPPING RATES EXAMPLE: RUSTINGTON – SECTION A (SEAWALL)

Profile Range 4d01053 to 4d01079

Highest CSA of any profile in this section (2003-2015)

Lowest CSA of any profile in this section (2003-2015)

Lowest Current CSA of any profile in this section (Summer 2015)

CSA threshold at which crest width disappears under 1 in 7 slope

CANTERBURY CITY COUNCIL

7 STANDARD OF PROTECTION

7-1 BASELINE CRITERIA

This chapter provides technical analysis and advice on management of shingle beaches. A shingle beach performs two coastal protection functions by breaking waves and absorbing wave energy, in addition to providing a physical barrier;

1. ***Prevention of Flooding:*** Reducing wave overtopping and preventing inundation

2. ***Protection of Coastal Structures:*** Preventing structural undermining and reducing wave impact damage, whilst providing toe weighting and structural support

These two factors are considered in unison in order to calculate the current standard of protection (SoP) and recommended beach levels. Typically the primary failure mechanism is excessive overtopping, flooding and damage to structures close to the beach. In this respect the defence can be considered to have a sub-standard level of protection, in most cases there will have to be a further reduction in beach levels before a breach or seawall failure becomes a significant risk.

Minimum beach levels are calculated by defining a maximum allowable overtopping limit for each section based on the tolerable discharge limits and the overtopping results for a 1:200 year storm (see Appendix G). Maintaining a beach level above this threshold achieves a present day standard of protection of > 1 in 200 years. **A 1 in 200 year SoP has been used throughout this report and all sister reports, throughout the South East, in order to provide consistency in reporting.**

It is not possible to present standard of protection results for every return period, instead for SoPs other than the 1:200 year the required trigger levels can be calculated from the overtopping graphs, calculated for a range of return periods from 1:1 to 1:200 years and these are provided in Appendix G.

A full structural assessment of sea defence structures, and failure probabilities, is outside the scope of this report. It does however consider the risk of structural undermining, based on the structure toe levels of the sea defence schematics (Appendix F). The analysis takes into account beach draw down during a storm in addition to calculating the potential scour depth at the structure. This allows for the calculation of a minimum beach required to prevent undermining. In the event that this is larger than the threshold calculated for overtopping the undermining CSA is used in preference when establishing trigger levels.

It should be noted that although the overtopping limit is based on providing a 1 in 200 year standard of protection, structural damage and undermining can result from relatively minor storms once the beach level has dropped below the critical threshold.

7-2 TRIGGER LEVELS

The naming convention and definition of trigger levels varies significantly between previous beach management plans and other reports. For the purpose of this report three trigger levels are used and described below for clarity. These were designed to help aid interpretation of coastal monitoring data and to inform beach management works.

CRITICAL LEVEL – This is the minimum beach level required to prevent overtopping exceeding tolerable limits in a 1:200 year storm event and/or a significant risk of structural damage or undermining. A Sub-Critical level is also defined which is the equivalent level for a standard of protection of 1:10 (approximately equal to half the CSA of the 1:200 event).

The problem with a critical level from a beach management perspective is that any beach at or just above this level may drop below it during a single storm or in short time under exposure to average conditions. This would require regular intervention and beach works to increase the beach level throughout the year, and even then potentially leave the area with a sub-standard standard of protection during a storm. As such it is unlikely a beach would be maintained at the critical level, but it provides a good reference for when emergency works are required and the urgency.

MAINTENANCE LEVEL – This level is higher than the critical level. The difference in beach cross sectional area is defined by the largest observed annual drop in beach level (since monitoring began in 2003), or where greater the largest loss during a storm event.

If beach levels are maintained above this level then it is highly unlikely that the beach size will reduce to below the critical level within a year or during a storm event. In reality in most years the beach level will only reduce by a fraction of this amount. Having a beach this size gives the coast protection authority time to plan works and be more efficient with little risk of levels dropping below the critical level.

DESIGN LEVEL – This is higher than the maintenance level and takes into consideration the impact of the defence failing (though undermining or significant overtopping), and builds in an appropriate factor of safety. When carrying out works, where possible, the beach size should be increased to this level.

Due to the maintenance level only referencing actual changes in beach size since 2003, there is always the possibility of a larger storm, or series of storms, that would reduce the beach size by more than the maintenance level. The design level accounts for this by adding a factor of safety; this is not a consistent figure for all locations but based on the potential impact of the defence being significantly overtopped or failing. For example a heavily urbanised area with properties below MHW would have a larger safety factor than a defence section protecting farmland. It also follows that erosive beaches have a higher design threshold than stable or accreting sections. This also allows time for remedial action and beach works following a storm event.

However, a larger beach may also be prone to higher rates of longshore transport, in particular in groyned sections of the coast.

It is important to note that CSAs within the Design Range (Yellow) and Maintenance Range (Orange) are above the 1:200 standard of protection. These areas give a factor of safety to allow time for coastal managers to intervene before the beach conditions drops below the required level of protection (Figure 7-1).

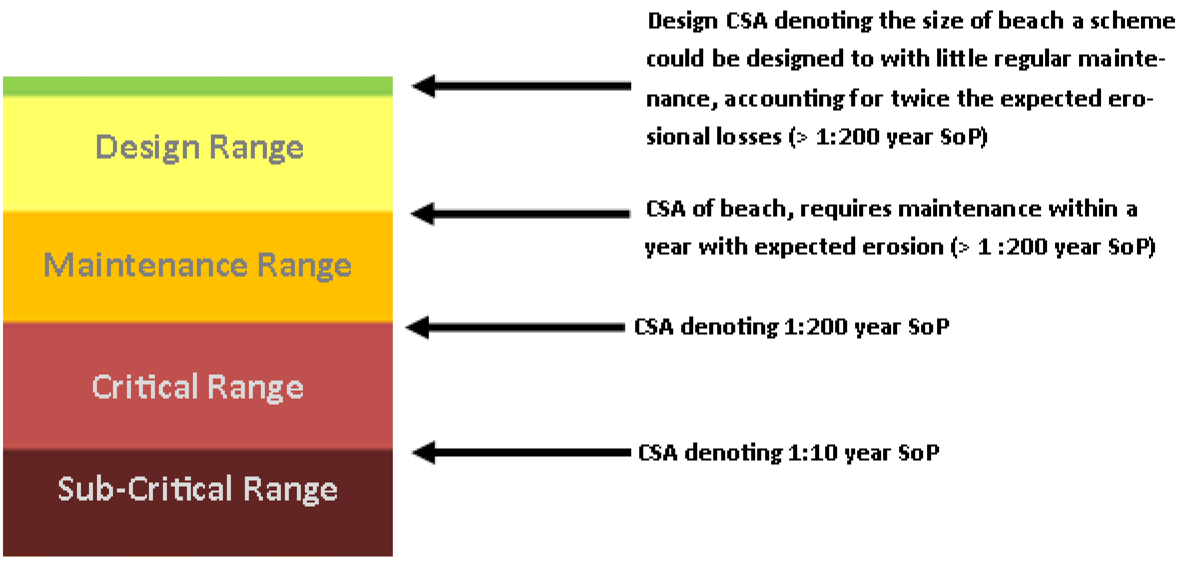


FIGURE 7-1 DESIGN, MAINTENANCE, CRITICAL AND SUB CRITICAL RANGES BASED ON TRIGGER LEVELS

7-3 CURRENT STANDARD OF PROTECTION

Having defined the trigger levels it is possible to ascertain not only the current standard of protection, but also to appraise how the beach has performed historically. Trigger levels are calculated as a beach cross sectional area (CSA) which are plotted for each profile location along the frontage and compared to the surveyed beach CSA through time. Profile locations overlain on aerial photography are provided in appendix D.

In order to condense this information so that the current standard of protection and historical performance can be viewed on a single graph for each management unit it is necessary to summarise the data for each profile as shown in Figure 7-2.

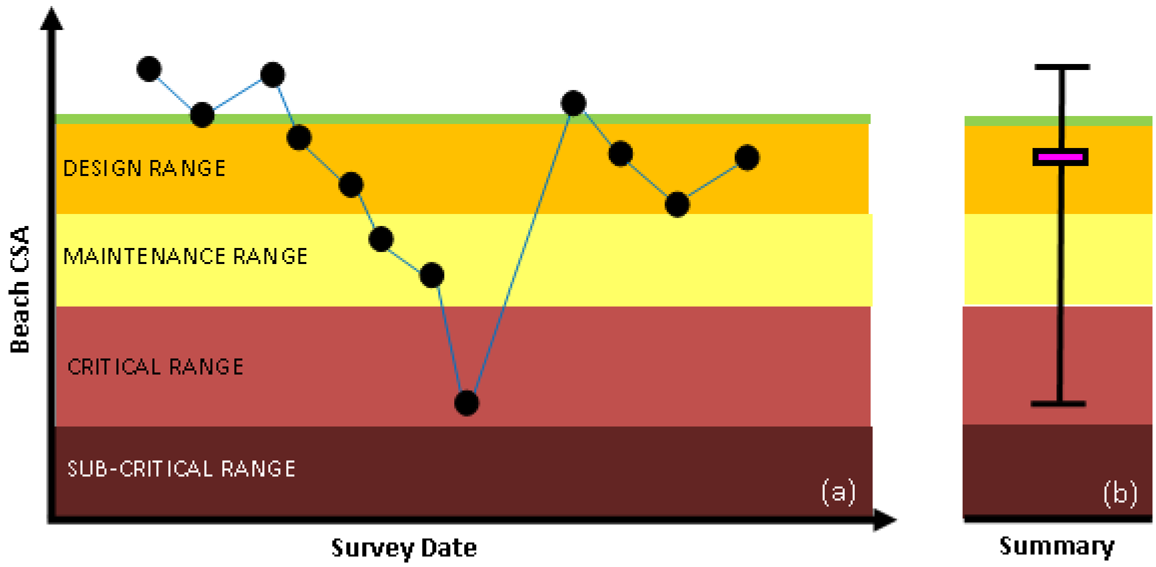


FIGURE 7-2 PRESENTATION OF STANDARD OF PROTECTION AND TRIGGER LEVELS

(a) Historic variation of beach levels (CSA)

(b) Summary of data, pink bar – current beach level, black bars – historic high and low

The following pages provide a graphical summary of the SoP for each management unit alongside key parameters for each defence section including the primary risk, critical cross-sectional area and defence types.

IMPORTANT NOTE:

Standards of protection and trigger levels defined in this report are based on current information and historic data at the time of writing. This report focusses on the 1 in 200 year SoP for consistency but please note it may not be appropriate at all sites to provide this SoP as the required protection could be higher or lower. The chosen SoP should be economically viable and site-appropriate. Coastal managers should be aware that several factors can result in a change to the SoP and/or trigger levels. These include, but are not limited to the following;

- Deterioration of seawall condition leading to an increase in required beach
- Seawall raising or repair reducing beach requirements and trigger levels
- New development behind the sea defence may necessitate a higher standard of protection and larger trigger levels
- Groyne failure can result in higher trigger levels due to increased susceptibility to erosion.
- Introduction of new or larger controlling structures
- Reduction of input sediment to the system due to changes to management practices down drift
- A significant change to the grading characteristics of the beach material
- Drop in foreshore levels allowing larger waves to reach the beach
- Climate change
- A change to the management regime for example from 'little and often' to 'large and infrequent' or vice versa.

7-3-1 LITTLEHAMPTON TO RUSTINGTON (4dSU18)

TABLE 7-3-1 LITTLEHAMPTON TO RUSTINGTON INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) L $M^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	ARUN DISTRICT COUNCIL	SEAWALL		OVERTOPPING	85	10	1,312	PROMENADE/SERVICE ROAD AND GREEN SPACE/CARPARK	
B		SEAWALL WITH RECURVE		OVERTOPPING	65	10		PROMENADE THEN ROAD	
C		CONCRETE REINFORCED PROMENADE		OVERTOPPING	70	10	0	PROMENADE THEN ROAD, SETBACK HOUSES	
D		TIMBER SEAWALL		OVERTOPPING	65	10		PROMENADE THEN ROAD, SETBACK HOUSES	
E		BRICK SEAWALL		OVERTOPPING	75	10		PROMENADE, SETBACK HOUSES	
F		CONCRETE REINFORCED PROMENADE		OVERTOPPING	50	10		SETBACK PROPERTY, BIG CREST	

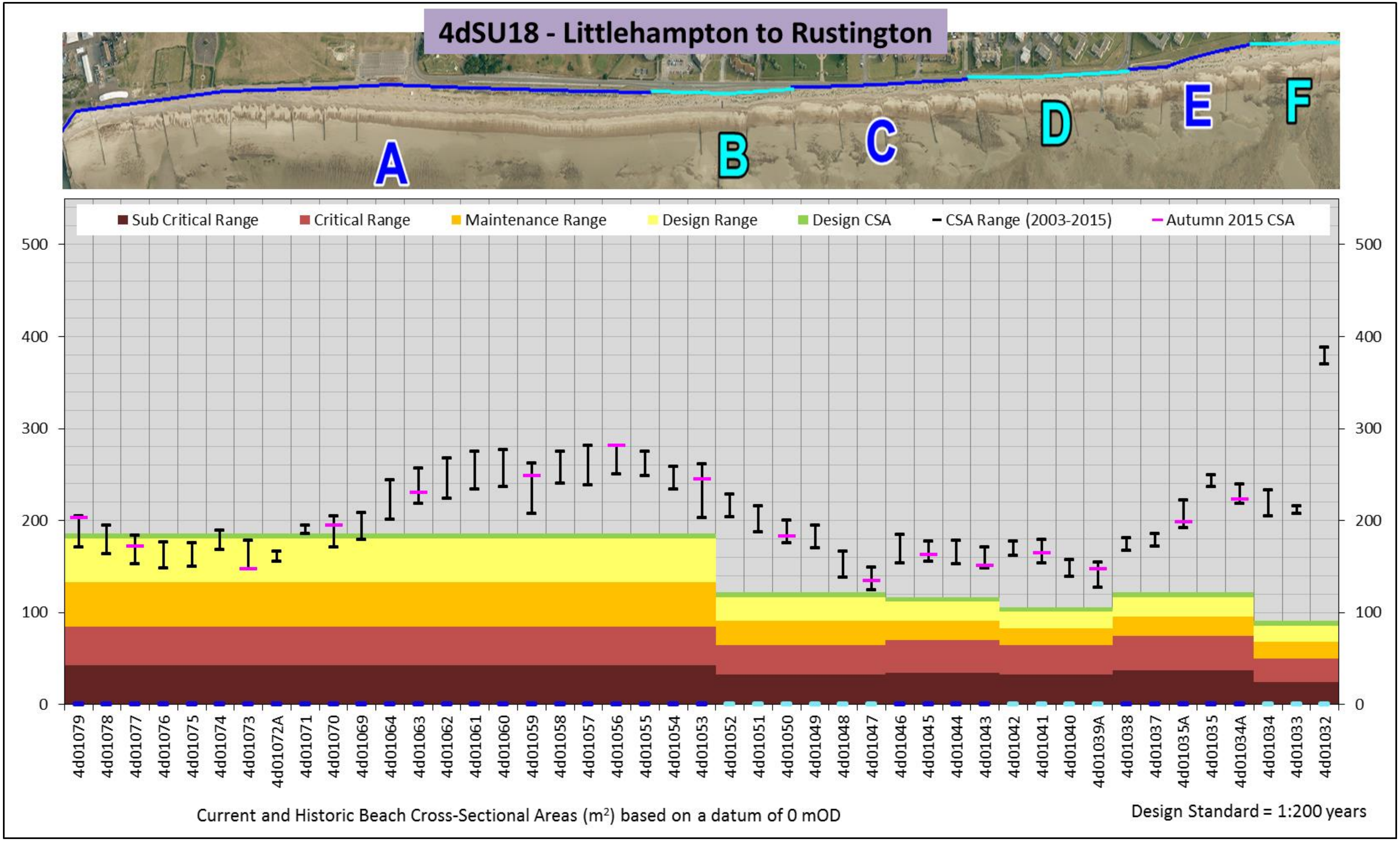


FIGURE 7-3-1 OBSERVED CSA CHANGES IN LITTLEHAMPTON TO RUSTINGTON (4DSU18) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-2 RUSTINGTON TO FERRING (4dSU17)

TABLE 7-3-2RUSTINGTON TO FERRING INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE RATE APPLICABLE) $LM^{-1}S^{-1}$	OT (IF	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	ARUN DISTRICT COUNCIL	GROYNED BEACH		OVERTOPPING	145	10		0	GREEN SPACE, SETBACK HOUSING	
B	ENVIRONMENT AGENCY	TIMBER SEAWALL		OVERTOPPING	75	10		13	CAFÉ AND BEACH HUTS, SETBACK HOUSING	
C	ARUN DISTRICT COUNCIL	GROYNED BEACH		OVERTOPPING	145	10		0	SETBACK HOUSES	
D		SEAWALL		OVERTOPPING	70	10			SETBACK HOUSES	
E	WORTHING BOROUGH COUNCIL/ARUN DISTRICT COUNCIL	GROYNED BEACH		OVERTOPPING	120	10			GREEN SPACE, FLAT AGRICULTURAL LAND	
F	WORTHING BOROUGH COUNCIL	GROYNED BEACH		OVERTOPPING	145	10		222	SETBACK BUT LOW LYING HOUSES AND ROAD	

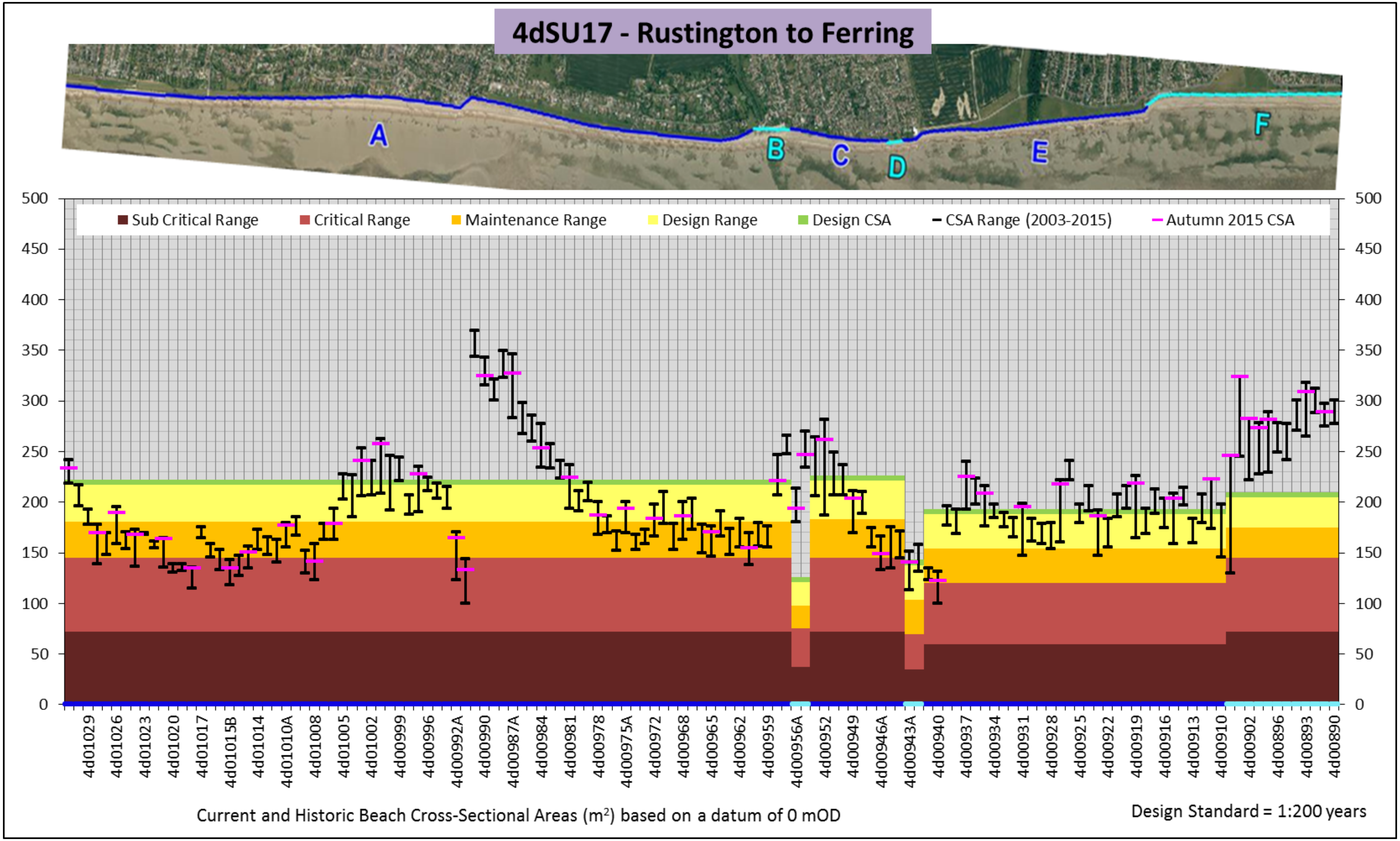


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FIGURE 7-3-2 OBSERVED CSA CHANGES IN RUSTINGTON TO FERRING (4DSU17) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-3 WORTHING (4dSU16)

TABLE 7-3-3 WORTHING INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) $LM^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	WORTHING BOROUGH COUNCIL	GROYNED BEACH		OVERTOPPING	150	10	0	BEACH HUTS, SETBACK HOUSING	
B		VERTICAL SEAWALL		OVERTOPPING	70	10		PROMENADE THEN ROAD	
C		ROCK REVETMENT		UNDERMINING	7.5	-		PROMENADE THEN ROAD	
D		VERTICAL SEAWALL		OVERTOPPING	70	10		PROMENADE THEN ROAD	
E		GROYNED BEACH		OVERTOPPING	130	10		PROMENADE THEN ROAD	
F		VERTICAL SEAWALL		OVERTOPPING	170	10		PROMENADE THEN ROAD	
G		GROYNED BEACH		OVERTOPPING	140	10		PROMENADE THEN ROAD	
H		SEAWALL		OVERTOPPING	125	10		ENTERTAINMENT CENTRE AND FAIRGROUND RIDES, PROMENADE THEN ROAD	
I		SEAWALL		OVERTOPPING	70	10		PIER	
J		GROYNED BEACH		OVERTOPPING	140	10		PROMENADE THEN ROAD	
K		SEAWALL WITH ROCK ARMOUR		UNDERMINING	-	-		ROAD THEN HOUSING	ROCK ARMOUR AND WALL COMBINATION SUFFICIENT TO PROVIDE SOP HENCE NO CSA DESIGN
L		GROYNED BEACH		OVERTOPPING	150	10		PROMENADE AND	

								SOME COMMERCIAL BUILDINGS	
M		VERTICAL SEAWALL		OVERTOPPING	70	10		GREEN SPACE AND CARPARK	
N		GROYNED BEACH		OVERTOPPING	145	10		FISHING BOATS, PROMENADE THEN SOME COMMERCIAL BUILDINGS	
O		ROCK REVETMENT		UNDERMINING	7.5	-		PROMENADE THEN ROAD	
P		GROYNED BEACH		OVERTOPPING	130	10		PROMENADE THEN ROAD	
Q		GROYNED BEACH	INCONSISTENT REAR WALL	OVERTOPPING	130	10		PROMENADE THEN ROAD	
R		GROYNED BEACH		OVERTOPPING	135	10	1,330	PROMENADE THEN ROAD	RIVER BASIN COULD BE FILLED BY LARGE TIDAL FLOOD EVENT
S	ENVIRONMENT AGENCY	TIMBER/CONCRETE SEAWALL		OVERTOPPING	70	10	0	HOUSES, BEACH HUTS	

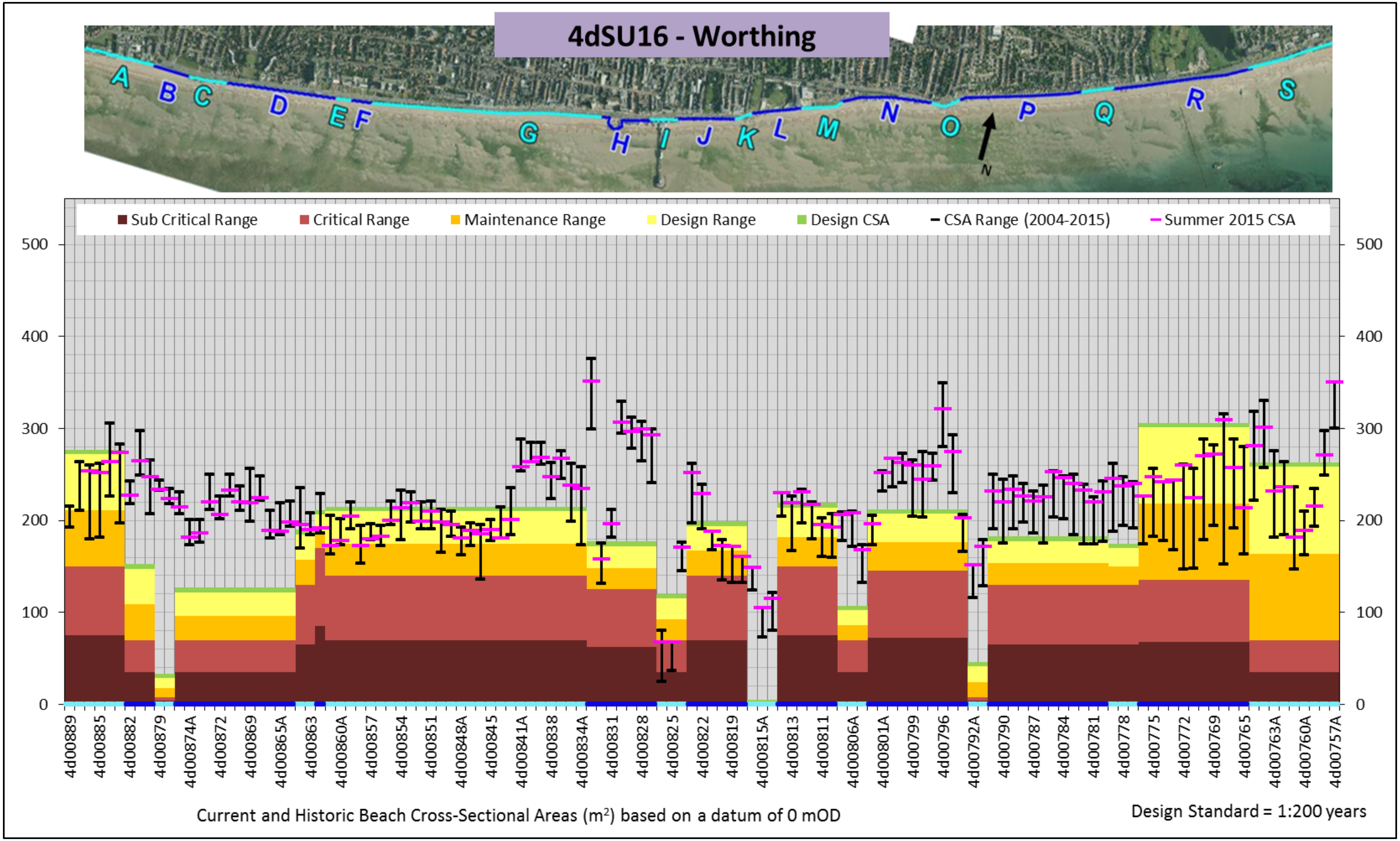


FIGURE 7-3-3 OBSERVED CSA CHANGES IN WORTHING (4DSU16) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-4 LANCING (4dSU15)

TABLE 7-3-4 LANCING INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) $LM^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	ENVIRONMENT AGENCY	GROYNED BEACH		OVERTOPPING	180	10	0	HOUSES	
B		TIMBER SEAWALL		OVERTOPPING	80	10		GREEN SPACE, SOME SETBACK PROPERTIES	
C		TIMBER SEAWALL		OVERTOPPING	95	10		CARAVAN SITE THEN HOUSES AND SALTWATER LAGOON	
D		GROYNED BEACH		OVERTOPPING	115	10		BEACH HUTS THEN SALTWATER LAGOON	
E		SEAWALL WITH RECURVE		OVERTOPPING	65	10		BEACH HUTS THEN PROMENADE	
F		GROYNED BEACH		OVERTOPPING	120	10		BIG BEACH THEN PROMENADE AND HOUSES	
G		GROYNED BEACH		OVERTOPPING	130	10		ROAD THEN HOUSES	
H		GROYNED BEACH		OVERTOPPING	115	10		BEACH HUTS THEN GREEN SPACE	
I		SMALL CONCRETE SEAWALL		OVERTOPPING	65	10		BIG BEACH THEN ROAD	
J		OPEN BEACH (SOME RELIC GROYNES)		OVERTOPPING	170	10		BIG BEACH THEN HOUSES	
K		HARBOUR ARM WITH CONCRETE SEAWALL		OVERTOPPING	60	50		UNOCCUPIED BEACHY SCRUBLAND	

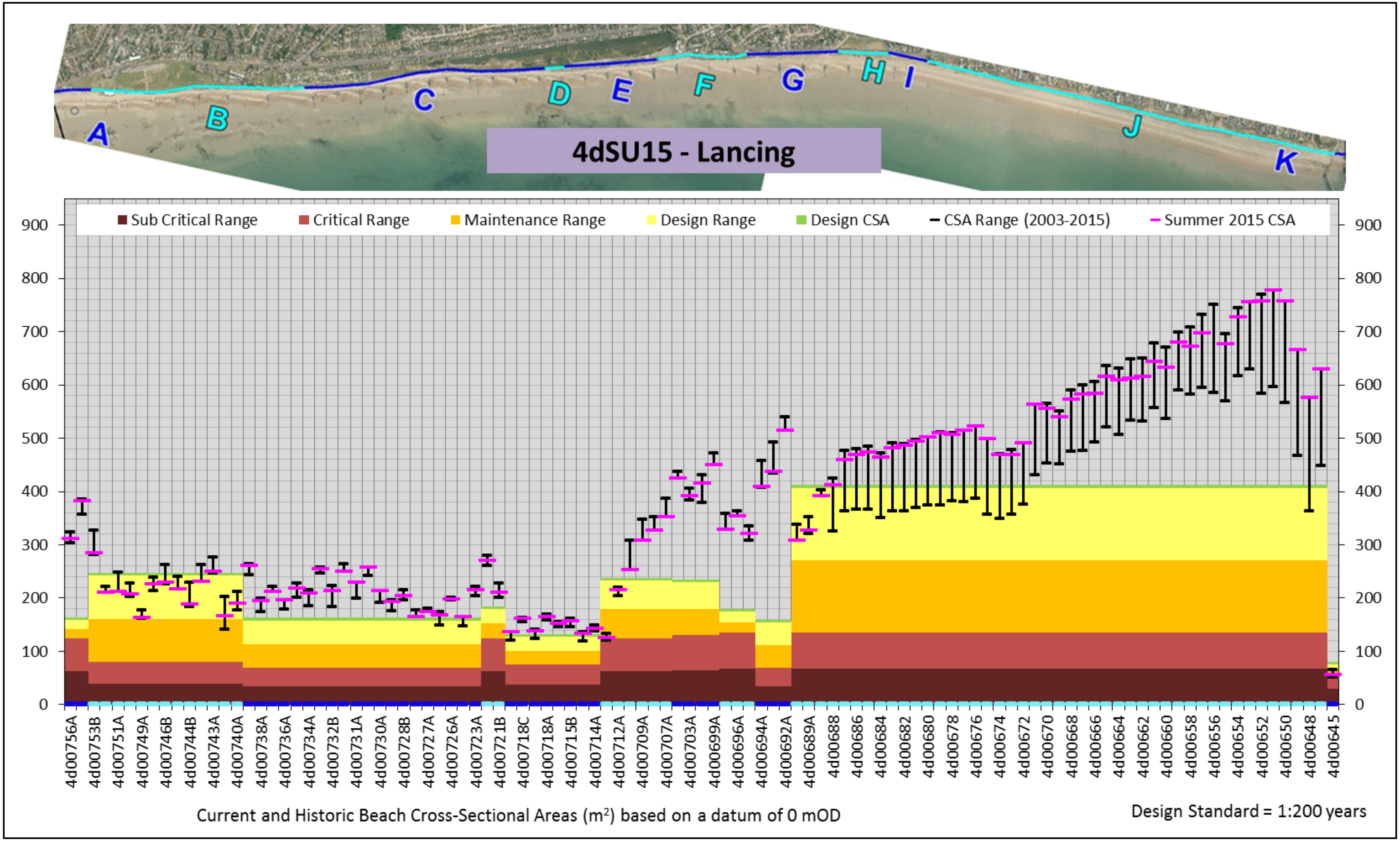


FIGURE 7-3-4 OBSERVED CSA CHANGES IN LANCING (4DSU15) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-1 SOUTHWICK (4dSU14)

TABLE 7-3-5 SOUTHWICK INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) $LM^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	SHOREHAM PORT AUTHORITY	SETBACK BUND		OVERTOPPING		10	0	ROAD THEN HOUSES	AREA BEHIND HARBOR HENCE NO CSA DESIGN
B		HARBOUR ARM	ROCK REVETMENT	OVERTOPPING		10		INDUSTRIAL BUILDINGS	ROCK REVETMENT SUFFICIENT, NO CSA DESIGN
C		SEAWALL WITH SEABEES	RECURVED REAR WALL	OVERTOPPING	55	10		INDUSTRIAL BUILDINGS	
D		VERTICAL SEAWALL		OVERTOPPING	75	10		INDUSTRIAL BUILDINGS	
E		SHEET PILING AND CONCRETE SEAWALL		OVERTOPPING	70	10		INDUSTRIAL BUILDINGS	
F		GROYNED BEACH		OVERTOPPING	135	10		ROAD THEN INDUSTRIAL BUILDINGS	
G		GROYNED BEACH		OVERTOPPING	140	10		ROAD THEN INDUSTRIAL BUILDINGS	
H		SHEET PILING WALL	TIMBER CRIB WALL (POOR CONDITION) WITH SOME CONCRETE WALL	OVERTOPPING	75	10		ROAD THEN INDUSTRIAL BUILDINGS	
I		CONCRETE SEAWALL		OVERTOPPING	75	10		ROAD THEN INDUSTRIAL BUILDINGS	
J		TIMBER		OVERTOPPING	70	10		ROAD THEN	

		SEAWALL						INDUSTRIAL BUILDINGS
K		GROYNED BEACH	SETBACK SHEET PILING WALL	OVERTOPPING	70	10		ROAD THEN INDUSTRIAL BUILDINGS
L	PRIVATE OWNER	GROYNED BEACH		OVERTOPPING	140	10		INDUSTRIAL AND COMMERCIAL BUILDINGS ON BEACH FRONT

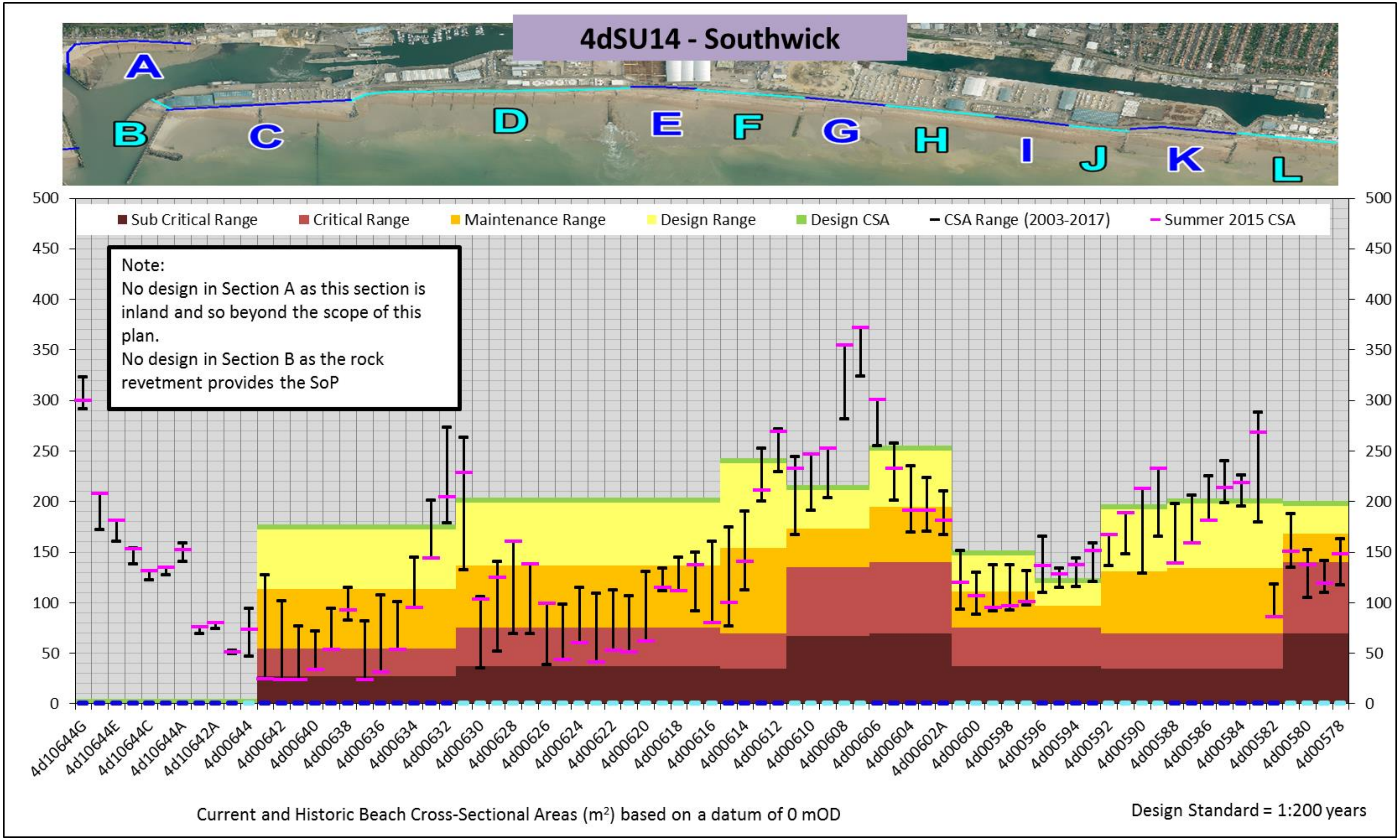


FIGURE 7-3-5 OBSERVED CSA CHANGES IN SOUTHWICK (4DSU14) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

7-3-2 BRIGHTON AND HOVE (4DSU13)

TABLE 7-3-6 BRIGHTON AND HOVE INTERPRETATION TABLE: RISK MECHANISM AND CONSEQUENCES

DEFENCE SECTION	OPERATOR	PRIMARY DEFENCE	SECONDARY DEFENCE	KEY RISK MITIGATED BY BEACH	CRITICAL CROSS SECTIONAL AREA (M^2)	ALLOWABLE OT RATE (IF APPLICABLE) $LM^{-1}S^{-1}$	NO. OF PROPERTIES IN FLOOD PLAIN	HINTERLAND	NOTES
A	BRIGHTON AND HOVE CITY COUNCIL	GROYNED BEACH		OVERTOPPING	140	10	0	CARPARK AND PROMENADE	
B		VERTICAL SEAWALL		OVERTOPPING	75	10		PROMENADE, THEN BEACH HUTS AND BOATING LAKE	
C		VERTICAL SEAWALL WITH STEPPED REVETMENT		OVERTOPPING	70	10		GREEN SPACE	
D		GROYNED BEACH		OVERTOPPING	140	10		GREEN SPACE	
E		VERTICAL SEAWALL		OVERTOPPING	75	10		PROMENADE, ROAD THEN COMMERCIAL BUILDINGS	
F		VERTICAL SEAWALL		OVERTOPPING	70	10		PROMENADE THEN FLATS	
G		CONCRETE VERTICAL SEAWALL		OVERTOPPING	70	10		PROMENADE, THEN BEACH HUTS THEN GREEN SPACE	
H		VERTICAL SEAWALL		OVERTOPPING	75	10		PROMENADE THEN GREEN SPACE	
I		PROMENADE WITH VARIOUS WALLS	SEAWALL WITH RECURVE	OVERTOPPING	135	10		AMENITY SPACE THEN PROMENADE THEN ROAD	
J		PROMENADE WITH VARIOUS WALLS	BRICK WALL WITH PROMENADE ON TOP	OVERTOPPING	140	10		AMENITY SPACE THEN PROMENADE THEN ROAD	

K		PROMENADE	BRICK WALL WITH PROMENADE ON TOP	OVERTOPPING	140	10		PROMENADE, THEN HIGHER PROMENADE THEN ROAD
L		PROMENADE WITH VARIOUS WALLS	BRICK WALL WITH PROMENADE ON TOP	OVERTOPPING	140	10		PROMENADE, THEN HIGHER PROMENADE THEN ROAD
M		CONCRETE PROMENADE	BRICK WALL WITH PROMENADE ON TOP	OVERTOPPING	155	10		PROMENADE, THEN HIGHER PROMENADE THEN ROAD
N		CONCRETE PROMENADE	BRICK WALL AND BUILDINGS	OVERTOPPING	155	10		BRIGHTON WHEEL AND PROMENADE
O		BRICK WALL		OVERTOPPING	140	10		MINIATURE RAILWAY THEN PROMENADE
P		CONCRETE WALL		OVERTOPPING	70	10		MINIATURE RAILWAY THEN PROMENADE
Q		BRICK WALL		OVERTOPPING	75	10		MINIATURE RAILWAY THEN AMENITY SPACE AND PROMENADE
R		CONCRETE PROMENADE		OVERTOPPING	70	10		MINIATURE RAILWAY THEN PROMENADE
S		CONCRETE SEAWALL WITH RETURN		OVERTOPPING	60	10		MINIATURE RAILWAY THEN PROMENADE
T		VERTICAL SEAWALL		OVERTOPPING	70	10		CARPARK THEN PROMENADE
U		CONCRETE SEAWALL		OVERTOPPING	75	10		PROMENADE

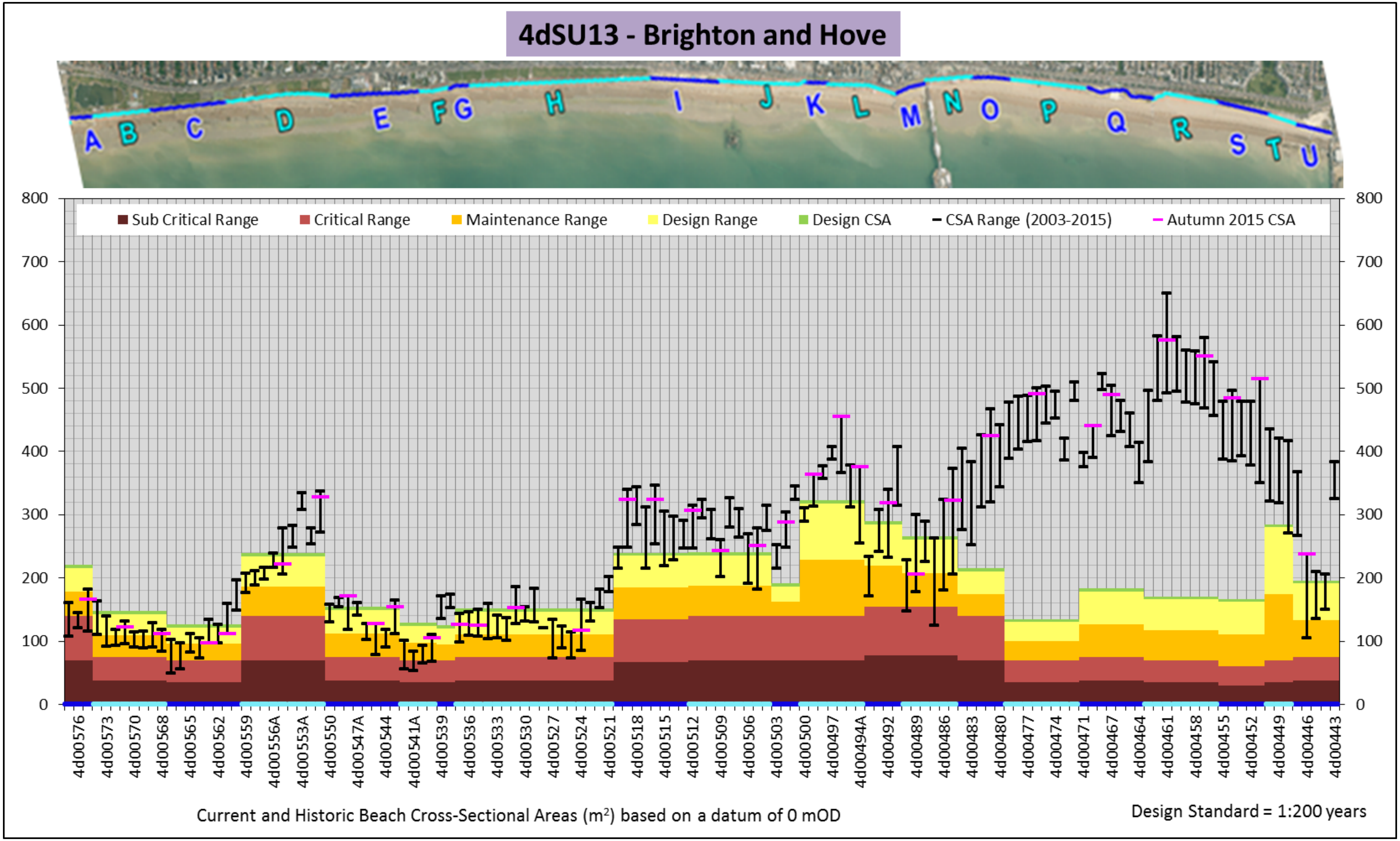


FIGURE 7-3-6 OBSERVED CSA CHANGES IN BRIGHTON AND HOVE (4DSU13) WITHIN THE CONTEXT OF BEACH TRIGGER LEVELS

8 BEACH MANAGEMENT PLAN

8-1 4dSU18 – LITTLEHAMPTON TO RUSTINGTON

8-1-1 MANAGEMENT SUMMARY

TABLE 8-1 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE LITTLEHAMPTON TO RUSTINGTON FRONTAGE (SURVEY UNIT 4DSU18)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M^3)+	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	ARUN DC	HTL	>1:200 (10) SEAWALL	706 (-9,125 TO 8,355)	MONITOR BEACH CSA	GATED VEHICULAR AND PLANT ACCESS WITH RAMPS
B			>1:200 (10) SEAWALL WITH RECURVE	331 (-1,853 TO 2,237)	MONITOR BEACH CSA	
C			>1:200 (10) CONCRETE REINFORCED PROMENADE	-251 (-1,729 TO 2,927)	MONITOR BEACH CSA	
D			>1:200 (10) TIMBER SEAWALL	-251 (-1,729 TO 2,927)	MONITOR BEACH CSA	
E			>1:200 (10) BRICK SEAWALL	-133 (-3,863 TO 2,251)	MONITOR BEACH CSA	
F			>1:200 (10) CONCRETE REINFORCED PROMENADE	-133 (-3,863 TO 2,251)	MONITOR BEACH CSA	GATED ACCESS

* Allowable overtopping is measured in l/m/s and determines the SoP
** The minimum CSA (m2) before undermining occurs (bold)
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-1-2 MANAGEMENT HOTSPOTS

All areas of the beach are currently above the 1 in 200 Standard of Protection so there is no immediate requirement for works or any hotspot areas. No beach management works have been required here previously as the beach is relatively sheltered from Littlehampton Harbour Arm.

8-1-3 RECOMMENDED FUTURE WORKS

Continued monitoring as part of the RCMP.

8-1-4 EMERGENCY WORKS

Should emergency works need to be carried out material may be redistributed from the eastern bays at Rustington which are well above design levels, or if more material is required may be brought in by barge or truck.

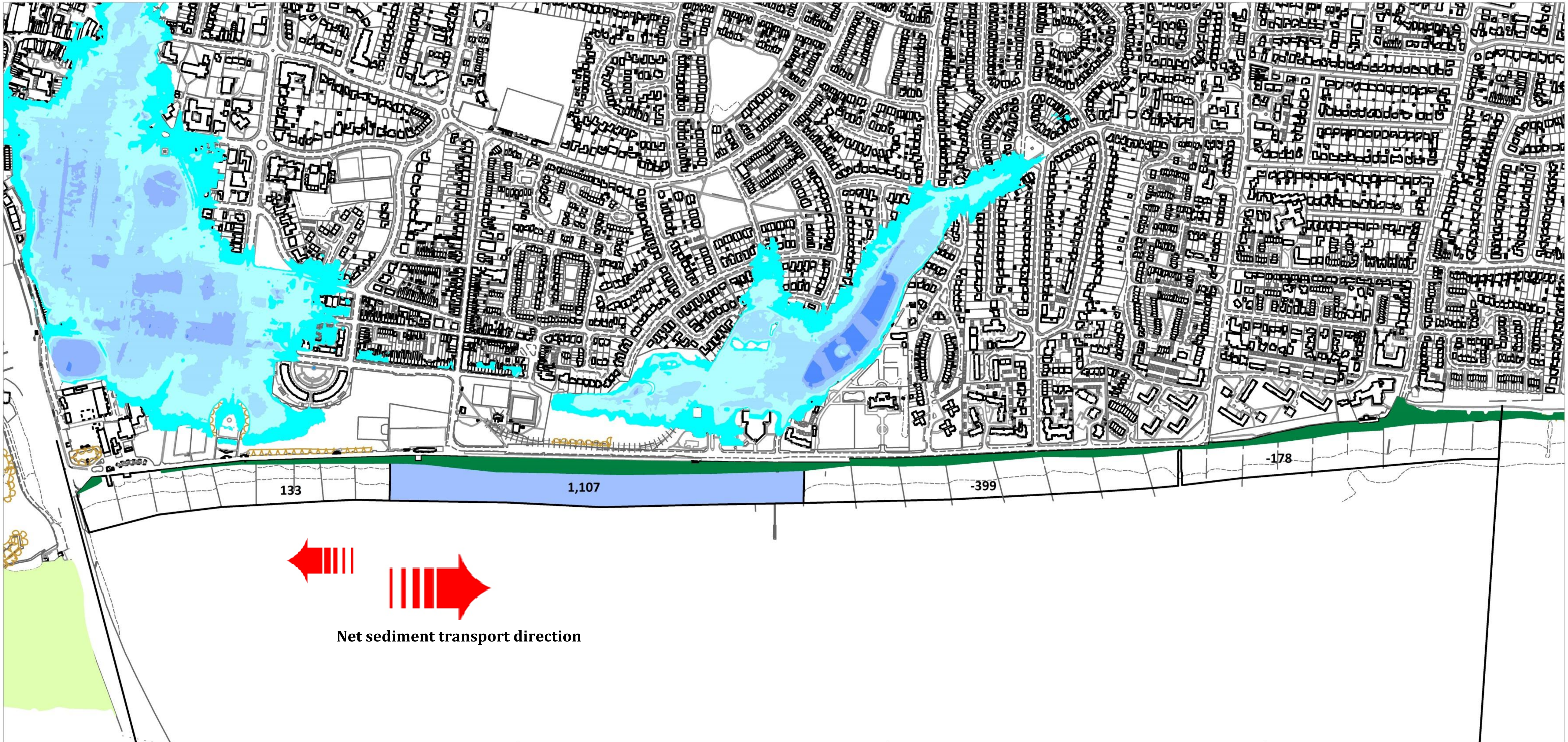


Figure 8-1 Summary of sediment budget transport rates, environmental restrictions and recommended management along the Rustington frontage

Polygons: Annual Average Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

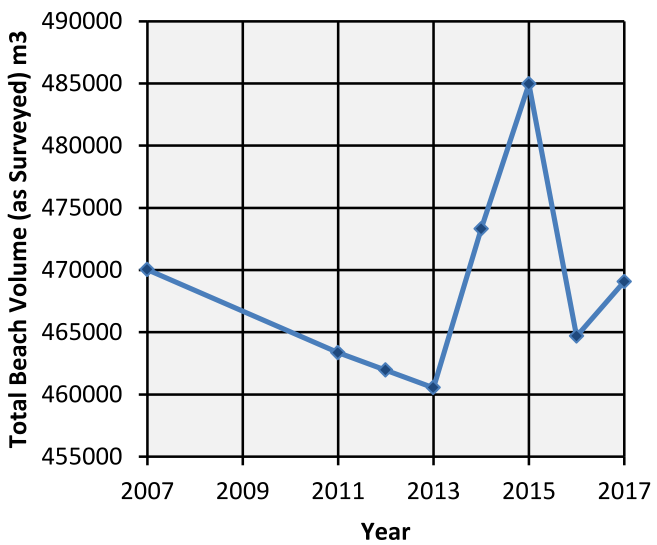
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

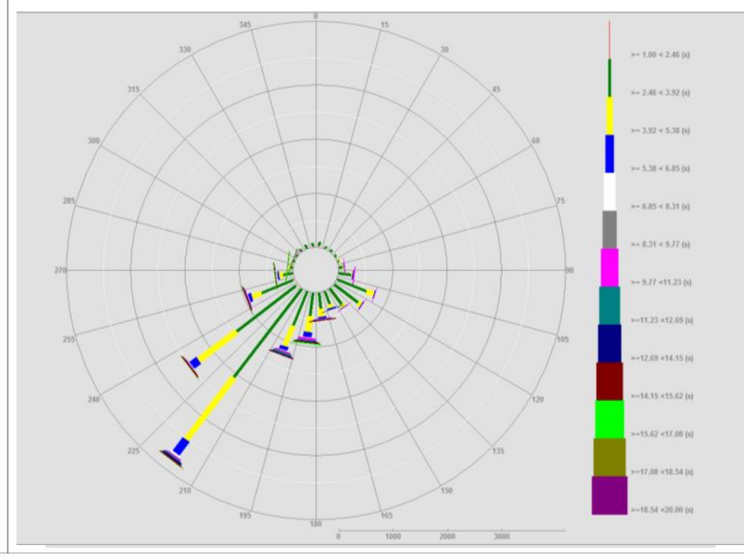
- 1:200 year extreme still water level planar flood map

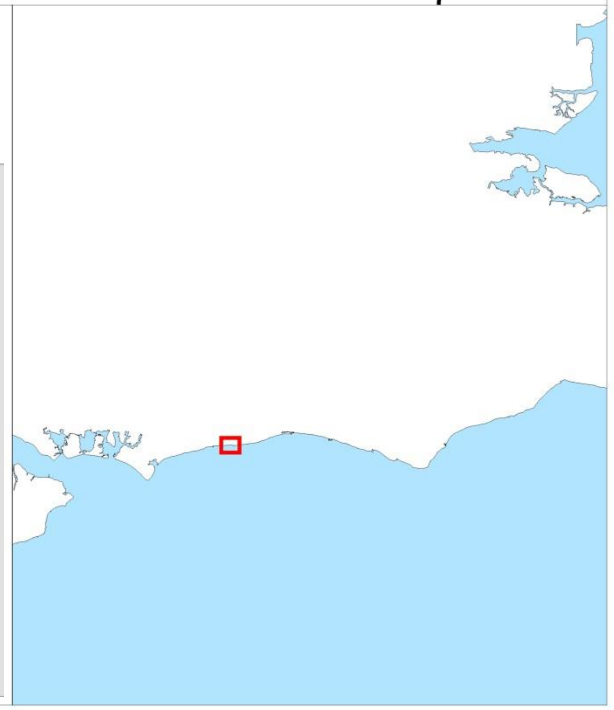
Map Scale 1: 7 000

Total Volume of Beach Material in Rustington Unit



Wave Rose for Rustington Bay showing direction, frequency & magnitude of waves. Jan 2007 – Jan 2017





8-2 4dSU17 – RUSTINGTON TO FERRING

8-2-1 MANAGEMENT SUMMARY

TABLE 8-2 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE RUSTINGTON TO FERRING FRONTAGE (SURVEY UNIT 4DSU17)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M^3)+	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	ARUN DC	HTL	1:100 (10) GROYNED BEACH	689 (-4,722 TO 7,948)	MONITOR BEACH CSA	
B	ENVIRONMENT AGENCY	HTL	>1:200 (10) TIMBER SEAWALL	35 (-862 TO 1,856)	MONITOR BEACH CSA	PLANT AND VEHICLE ACCESS
C	ARUN	HTL	1:200 (10) GROYNED BEACH	135 (-3,018 TO 1,584)	MONITOR BEACH CSA	
D	ARUN	HTL	>1:200 (10) SEAWALL	45 (-642 TO 353)	MONITOR BEACH CSA	
E	WORTHING	HTL	>1:20 < 1:50 (10) GROYNED BEACH	109 (-6,167 TO 19,170)	MONITOR BEACH CSA	
F	WORTHING	HTL	>1:200 (10) GROYNED BEACH	2,371 (-813 TO 12,490)	MONITOR BEACH CSA	VEHICLE ACCESS

* Allowable overtopping is measured in l/m/s and determines the SoP
** The minimum CSA (m2) before undermining occurs (bold)
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-2-2 MANAGEMENT HOTSPOTS

There are two pinch points along the frontage where the CSA chart shows that the beach levels are close to the critical level (midway along Section A and at the western end of Section E). A large proportion of the profiles are within the maintenance range, although of these many are at the highest they have ever been as they are at top of their historical levels.

8-2-3 RECOMMENDED FUTURE WORKS

Continued monitoring as part of the RCMP.

8-2-4 EMERGENCY WORKS

In an emergency material may be redistributed from the groyne bays which are above design, not disturbing any vegetated shingle, to those requiring material. If more material is needed it may be brought in by barge or truck.

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FIGURE 8-6: SUMMARY OF SEDIMENT TRANSPORT RATES, ENVIRONMENTAL RESTRICTIONS, AREAS OF CONCERN AND RECOMMENDED MANAGEMENT ALONG THE FERRING FRONTAGE

Polygons: Annual Average

Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

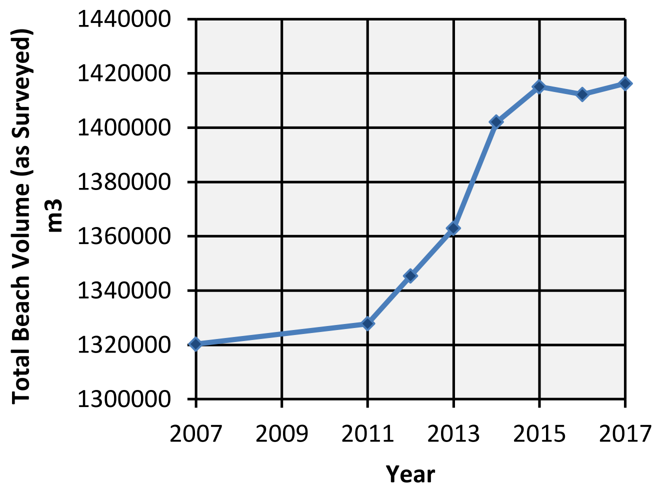
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

- 1:200 year extreme still water level planar flood map

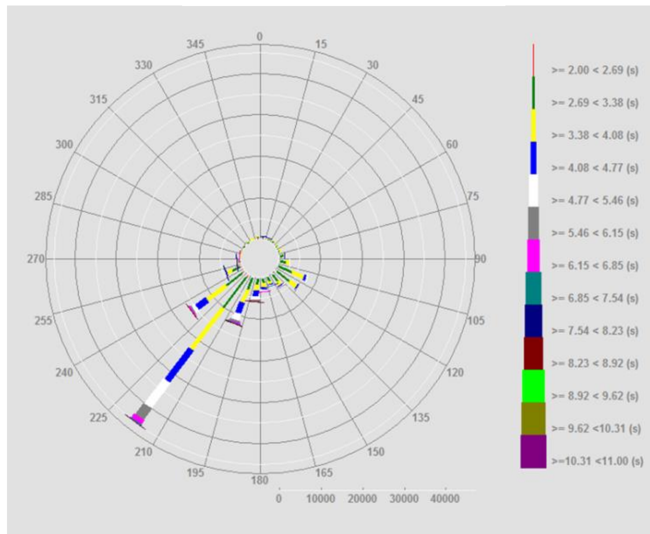
Map Scale 1: 18 000

Total Volume of Beach Material in Ferring Unit (2007-2017)



Wave Rose for Rustington Bay showing direction, frequency & magnitude of waves,

Jan 2007 – Jan 2017



8-3 4dSU16 – WORTHING

8-3-1 MANAGEMENT SUMMARY

TABLE 8-3 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE WORTHING FRONTAGE (SURVEY UNIT 4DSU16)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M³)⁺	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	WORTHING DC	HTL	>1:200 (10) GROYNED BEACH	521 (-3,292 TO 7,946)	MONITOR BEACH CSA	GATED VEHICULAR ACCESS
B			>1:200 (10) VERTICAL SEAWALL	260 (-1,646 TO 3,973)	MONITOR BEACH CSA	GATED VEHICULAR AND PLANT ACCESS WITH RAMP
C			>1:200 (10) ROCK REVETMENT	260 (-1,646 TO 3,973)	MONITOR ROCK REVETMENT	GATED VEHICULAR AND PLANT ACCESS WITH RAMP
D			>1:200 (10) VERTICAL SEAWALL	373 (-12,318 TO 10,538)	MONITOR BEACH CSA	VEHICULAR GATED ACCESS
E			>1:200 (10) GROYNED BEACH	124 (-4,106 TO 3,513)	MONITOR BEACH CSA	VEHICULAR GATED ACCESS
F			>1:200 (10) VERTICAL SEAWALL	-6 (-1,825 TO 1,702)	MONITOR BEACH CSA	VEHICULAR GATED ACCESS
G			>1:200 (10) GROYNED BEACH	-173 (-12,516 TO 10,067)	MONITOR BEACH CSA	VEHICULAR GATED ACCESS
H			< 1:1 (10) SEAWALL	368 (-3,489 TO 1,843)	MONITOR BEACH CSA AND LIDO	VEHICULAR GATED ACCESS
I			1:50 (10) SEAWALL	-	MONITOR BEACH CSA	GATED PLANT ACCESS
J			>1:200 (10) GROYNED BEACH	394 (-6,977 TO 3,686)	MONITOR BEACH CSA	GATED ACCESS
K			>1:200 (10) SEAWALL WITH ROCK ARMOUR	-	MONITOR DEFENCES	GATED ACCESS
L			>1:200 (10) GROYNED BEACH	613 (-4,266 TO 5,802)	MONITOR BEACH CSA	
M			>1:200 (10) VERTICAL SEAWALL	613 (-4,266 TO 5,802)	MONITOR BEACH CSA	GATED VEHICULAR ACCESS
N			>1:200 (10) GROYNED BEACH	613 (-4,266 TO 5,802)	MONITOR BEACH CSA	PLANT ACCESS
O			>1:200 (10) ROCK REVETMENT	-	MONITOR ROCK REVETMENT	
P			>1:200 (10) GROYNED BEACH	938 (-3,135 TO 2,652)	MONITOR BEACH CSA	

Q			>1:200 (10) GROYNED BEACH	469 (-1,568 TO 1,326)	MONITOR BEACH CSA	
E			>1:200 (10) GROYNED BEACH	1,774 (-4,269 TO 4,455)	MONITOR BEACH CSA	GATED ACCESS
S			>1:200 (10) TIMBER/CONCRETE SEAWALL	1,305 (-5,157 TO 3,291)	MONITOR BEACH CSA	

* The minimum CSA (m^2) before undermining occurs (bold)
** Allowable overtopping is measured in l/m/s and determines the SoP
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-3-2 MANAGEMENT HOTSPOTS

All of the profiles at Worthing are well above the design level with the exception of two profiles, 4d00831 and 4d00832. The profiles, which are within Section G, are in the design and maintenance range – this is due to the presence of the bandstand which is seaward of the rest of the defence.

8-3-3 RECOMMENDED FUTURE WORKS

The short section in front of the bandstand should be carefully monitored for any signs of damage. The rest of the frontage should benefit from continued monitoring as part of the RCMP.

8-3-4 EMERGENCY WORKS

In an emergency material may be redistributed from the groyne bays which are above design.

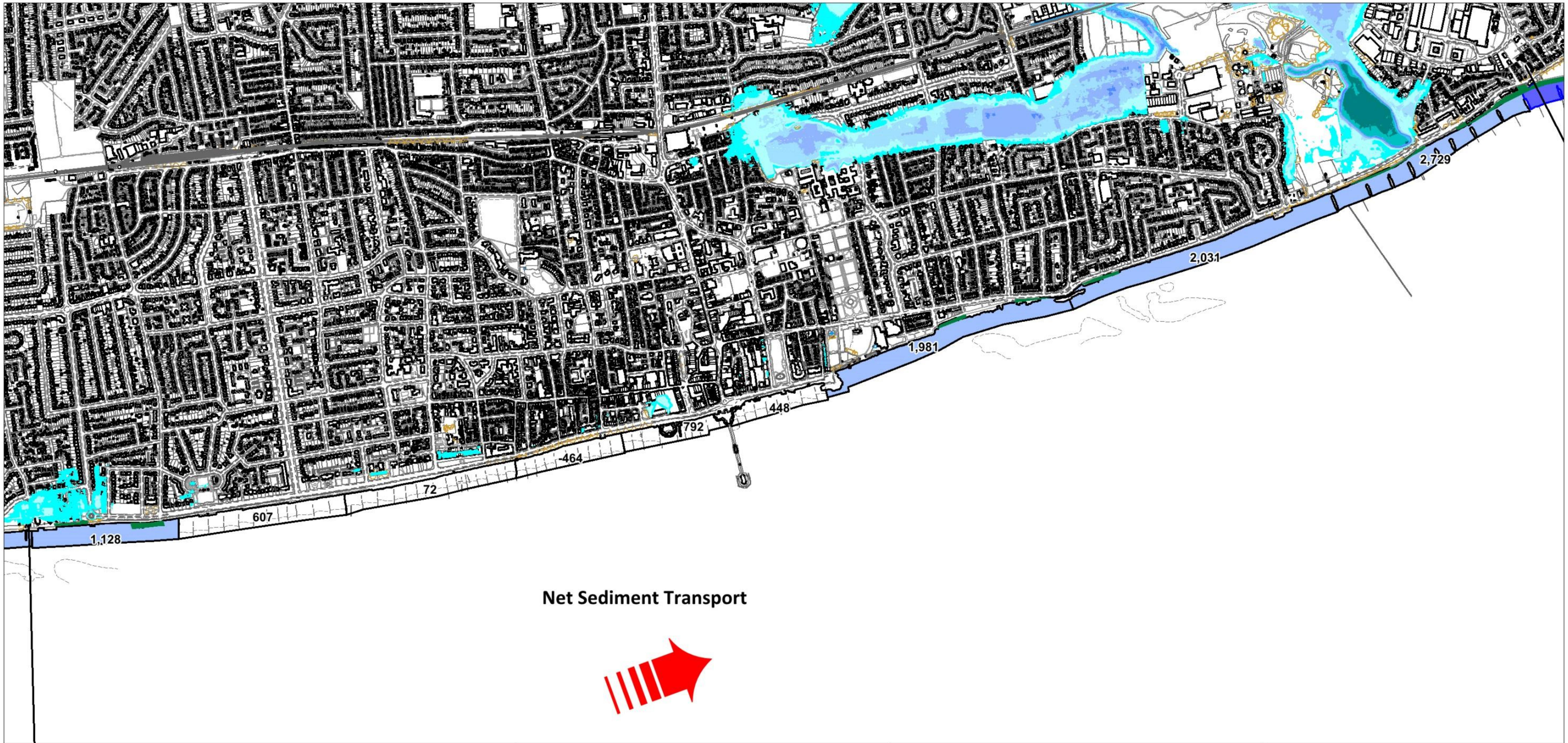


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FIGURE 8-3 SUMMARY OF SEDIMENT BUDGET TRANSPORT RATES, ENVIRONMENTAL RESTRICTIONS AND RECOMMENDED MANAGEMENT ALONG THE WORTHING FRONTAGE

Polygons: Annual Average

Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

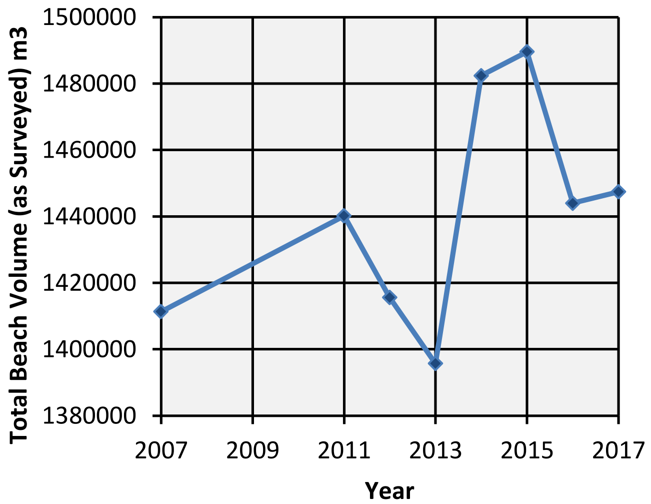
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

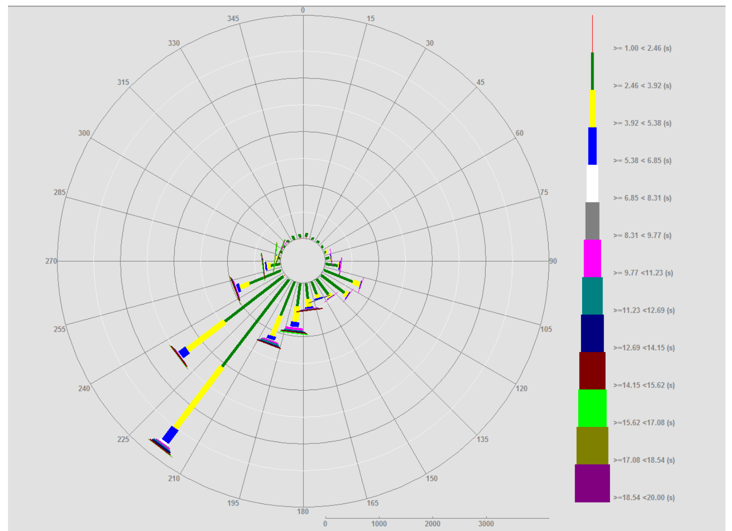
- 1:200 year extreme still water level planar flood map

Map Scale 1: 18 000

Total Volume of Beach Material in Worthing Unit (2007-2017)



Wave Rose for Rustington Bay showing direction, frequency & magnitude of waves, Jan 2007 – Jan 2017



8-4 4dSU15 – LANCING

8-4-1 MANAGEMENT SUMMARY

TABLE 8-4 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE LANCING FRONTAGE (SURVEY UNIT 4DSU15)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M^3)+	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	ENVIRONMENT AGENCY	HTL	>1:200 (10) GROYNED BEACH	372 (-1,771 TO 4,200)	MONITOR BEACH CSA	
B			>1:200 (10) TIMBER SEAWALL	1,858 (-8,857 TO 21,002)	MONITOR BEACH CSA	VEHICULAR AND PLANT ACCESS
C			>1:200 (10) TIMBER SEAWALL	-2,048 (-18,825 TO 16,735)	MONITOR BEACH CSA	LNR
D			>1:200 (10) GROYNED BEACH	-243 (-928 TO 1,221)	MONITOR BEACH CSA	LNR
E			>1:200 (10) SEAWALL WITH RECURVE	-1,217 (-4,641 TO 6,103)	MONITOR BEACH CSA	VEHICULAR ACCESS LNR.
F			1:100 (10) GROYNED BEACH	-996 (-6,368 TO 1,362)	MONITOR BEACH CSA	VEHICULAR ACCESS LNR
G			>1:200 (10) GROYNED BEACH	-996 (-6,368 TO 1,362)	MONITOR BEACH CSA	LNR
H			>1:200 (10) GROYNED BEACH	-498 (-3,184 TO 681)	MONITOR BEACH CSA	GATED ACCESS LNR
I			>1:200 (10) SMALL CONCRETE SEAWALL	-498 (-3,184 TO 681)	MONITOR BEACH CSA	LNR
J			>1:200 (10) OPEN BEACH (SOME RELIC GROYNES)	28,745 (2,347 TO 139,559)	MONITOR BEACH CSA	LNR
K			> 1:100 > 1:200 (50) HARBOUR ARM WITH CONCRETE SEAWALL	372 (-1,771 TO 4,200)	MONITOR BEACH CSA	GATED PLANT ACCESS. LNR

* The minimum CSA (m^2) before undermining occurs (bold)
** Allowable overtopping is measured in l/m/s and determines the SoP
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-4-2 MANAGEMENT HOTSPOTS

The profiles at Lancing are well above design. The new rock groyne scheme along the frontage has helped to provide this level of protection.

Beach west of Harbour Arm

The presence of the Harbour Arm acts as a terminal groyne and encourages deposition of material along the beach. This starves the beach downdrift of material, see 8-5-2 Southwick Management Hotspots.

8-4-3 RECOMMENDED FUTURE WORKS

Beach west of Harbour Arm

Material is currently by-passed from this section of coast to Southwick; this method is removing vast quantities of shingle from the closed sediment cell of Littlehampton Harbour to Shoreham Port. Currently, this cell appears to be gaining c.40,000m^3 per year and remains very healthy. If this pattern changes in the future, i.e. if the sediment cell stops gaining material, it would be recommended to recycle within the sediment cell.

Depending on the distance of between the extraction and deposition sites material could be trucked or barged to the deposition site. Further calculations would be required to establish the lower carbon footprint and the cost implications of both methods. If consideration is given to barging the material, it would recommended to deposit sediment either in Rustington or Ferring as sediment would eventually travel through the whole sediment system, reaching Shoreham once again.

Continued monitoring as part of the RCMP.

8-4-4 EMERGENCY WORKS

Material may be taken from Section K which is above design and may be redistributed to the rest of unit as need be. As this section of beach is expansive and as the sediment cell is gaining c.40,000m^3 per year, material may be redistributed to areas outside of the unit. After stormy weather, material is most likely to be required at Sections C and D of 4dSU14 Southwick.

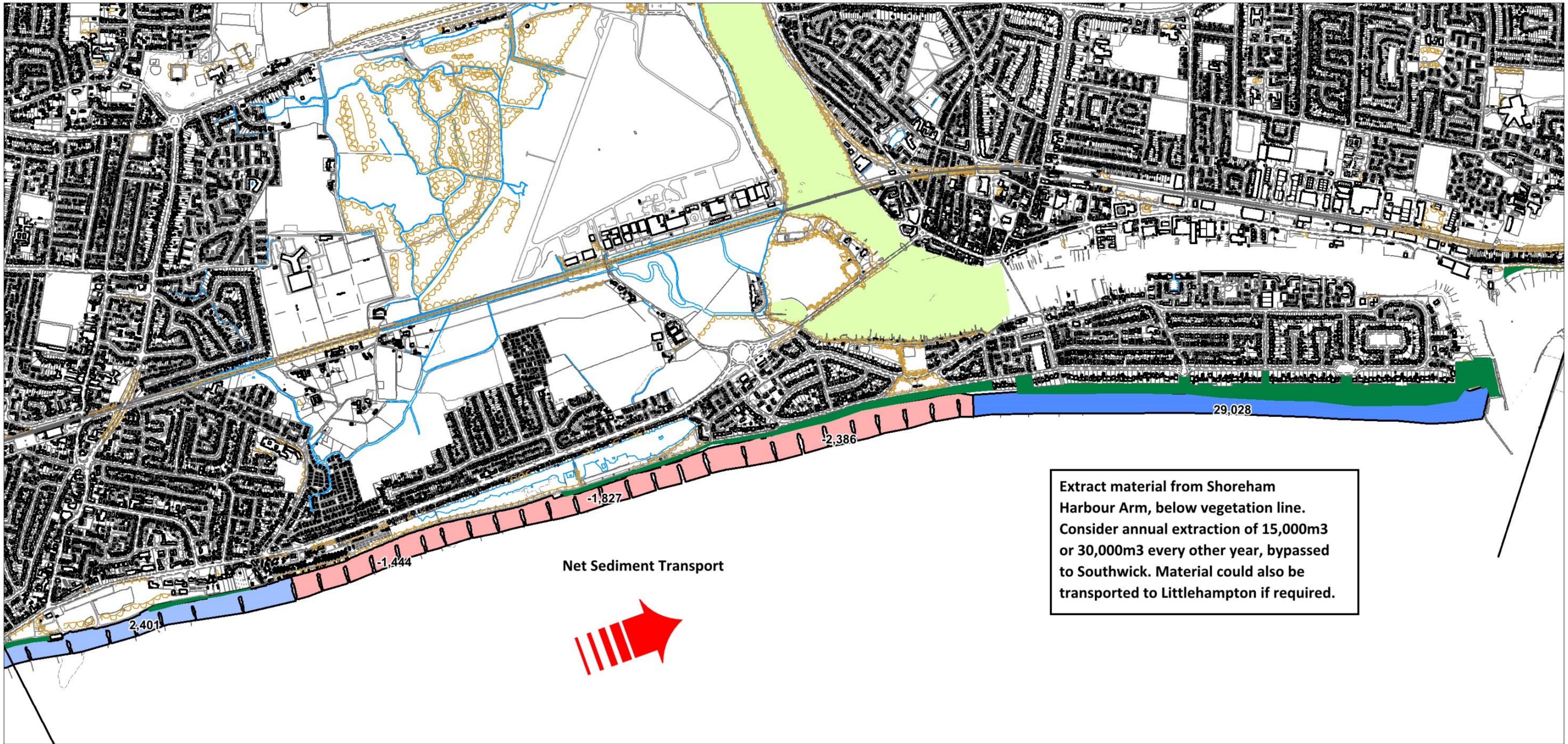


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FIGURE 8-4 SUMMARY OF SEDIMENT BUDGET TRANSPORT RATES, ENVIRONMENTAL RESTRICTIONS AND RECOMMENDED MANAGEMENT ALONG THE LANCING FRONTAGE

Polygons: Annual Average Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

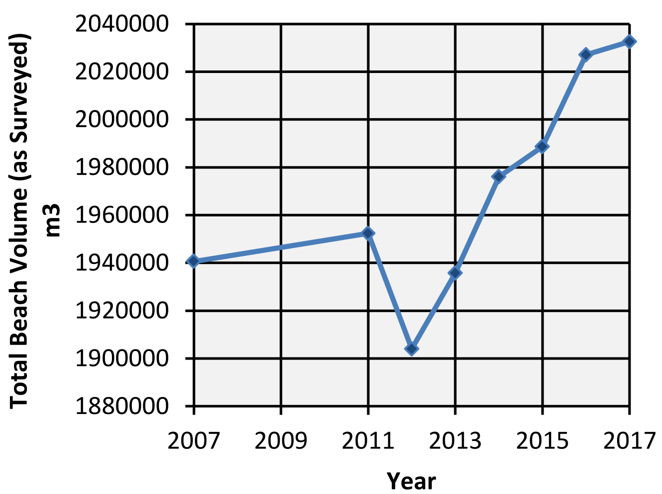
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

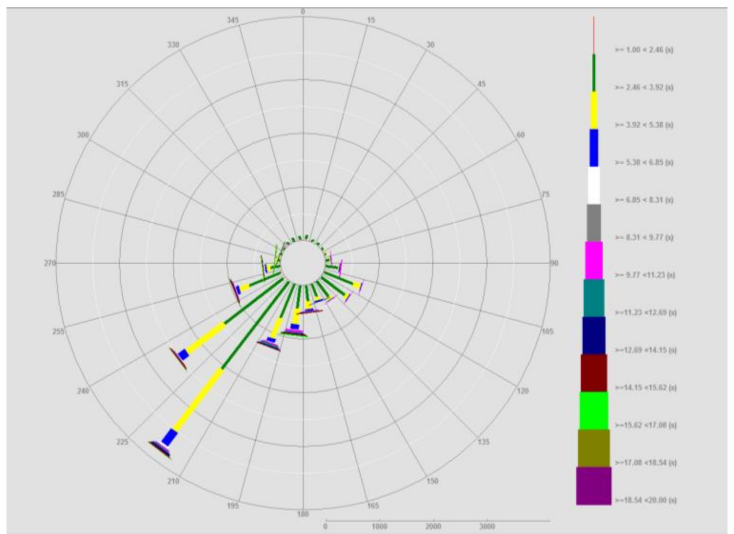
- 1:200 year extreme still water level planar flood map

Map Scale 1: 14 000

Total Volume of Beach Material in Lancing Unit (2007-2017)



Wave Rose for Rustington Bay showing direction, frequency & magnitude of waves, Jan 2007 – Jan 2017



8-5 4dSU14 – SOUTHWICK

8-5-1 MANAGEMENT SUMMARY

TABLE 8-5 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE SOUTHWICK FRONTAGE (SURVEY UNIT 4DSU14)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M3)+	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	SHOREHAM PORT AUTHORITY	HTL	(10) SETBACK BUND	-	MONITOR BEACH CSA	
B			(10) HARBOUR ARM	-	MONITOR BEACH CSA	
C			1:100 (10) SEAWALL WITH SEABEAS	-17,105 (-40,539 TO -5,487)	MONITOR BEACH CSA	PLANT ACCESS
D			<1:1 (10) VERTICAL SEAWALL	335 (-13,660 TO 11,062)	MONITOR BEACH CSA	
E			>1:200 (10) SHEET PILING AND CONCRETE SEAWALL	61 (-1,860 TO 2,108)	MONITOR BEACH CSA	PLANT ACCESS
F			>1:200 (10) GROYNED BEACH	123 (-3,720 TO 4,217)	MONITOR BEACH CSA	PLANT ACCESS
G			>1:200 (10) GROYNED BEACH	61 (-1,860 TO 2,108)	MONITOR BEACH CSA	
H			>1:200 (10) SHEET PILING WALL	123 (-3,720 TO 4,217)	MONITOR BEACH CSA	
I			>1:200 (10) CONCRETE SEAWALL?	61 (-1,860 TO 2,108)	MONITOR BEACH CSA	
J			>1:200 (10) TIMBER SEAWALL	61 (-1,860 TO 2,108)	MONITOR BEACH CSA	
K			>1:200 (10) GROYNED BEACH	-211 (-5,177 TO 3,794)	MONITOR BEACH CSA	
L			>1:5 <1:10 (10) GROYNED BEACH	--211 (-5,177 TO 3,794)	MONITOR BEACH CSA	GATED PLANT ACCESS LNR

* The minimum CSA (m^2) before undermining occurs (bold)
** Allowable overtopping is measured in l/m/s and determines the SoP
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-5-2 MANAGEMENT HOTSPOTS

Due to the large Harbour Arm, blocking the sediment supply and causing scour, Southwick is a highly erosive section. Sections C, D and L all have profiles within critical range. The hinterland here is an industrial area.

The sediment budget shows that the material recycled into Southwick is not retained (because of the scour from the Harbour Arm. Therefore to maintain a beach, approximately 15,000m^3, needs to be imported each year. Alternatively 30,000m^3 could be recycled every other year if this makes using a barge more feasible. Ideally, material should be sourced from within the Southwick to Brighton sediment cell rather than the Littlehampton to Lancing cell as both are closed cells.

8-5-3 RECOMMENDED FUTURE WORKS

To raise the standard of protection here the beach levels must be raised. This may be done through a series of beach recharge/recycling works however without controlling structures the impacts of these beach management works may be short lived. As the sediment cell to the west is gaining 40,000m^3 per year it does not do any harm to redistribute that material here, however it does need to be done every year.

Continued monitoring as part of the RCMP.

8-5-4 EMERGENCY WORKS

Material may be imported from Shoreham Harbour Arm. In adverse weather conditions this may need to be done by road rather than barge.

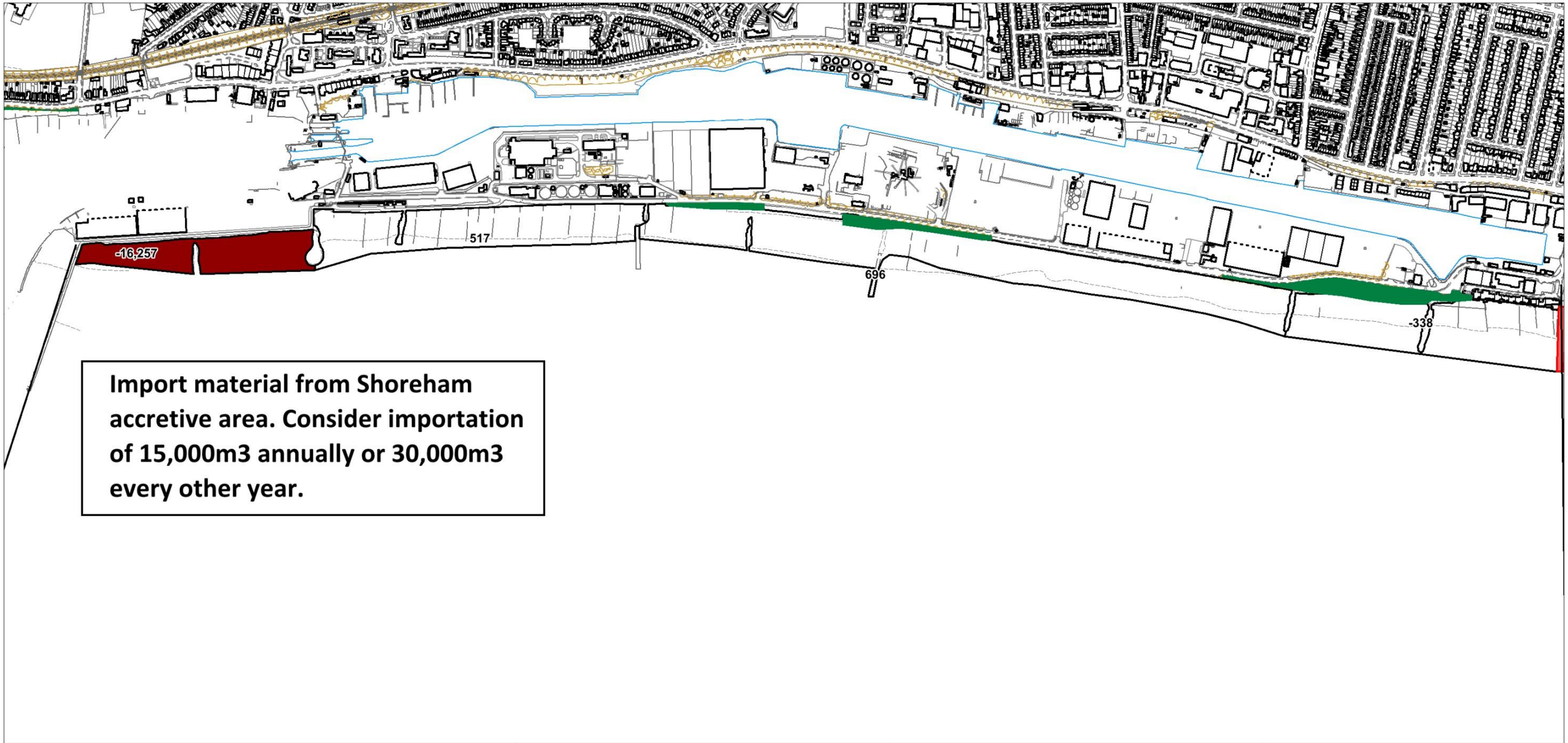


FIGURE 8-5 SUMMARY OF SEDIMENT BUDGET TRANSPORT RATES, ENVIRONMENTAL RESTRICTIONS AND RECOMMENDED MANAGEMENT ALONG THE SOUTHWICK FRONTAGE

Polygons: Annual Average Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

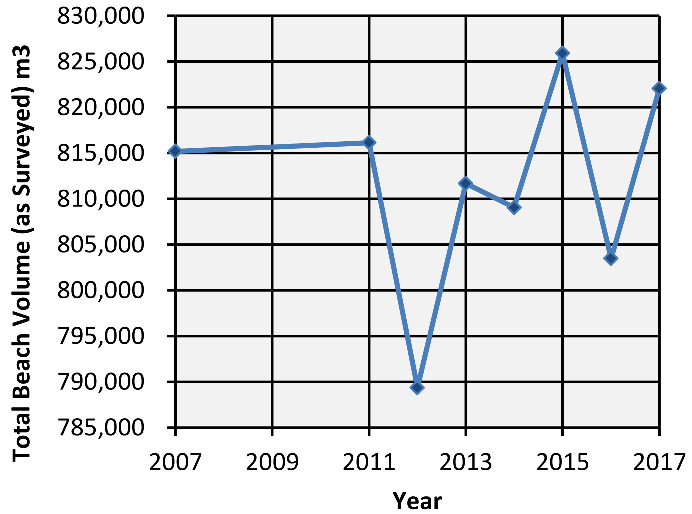
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

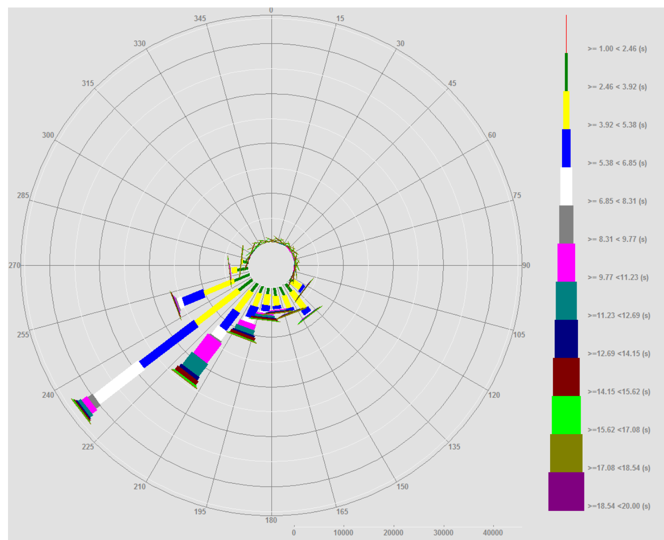
- 1:200 year extreme still water level planar flood map

Map Scale 1: 8,000

Total Volume of Beach Material in Southwick Unit (2007-2017)



Wave Rose for Seaford showing direction, frequency & magnitude of waves Jan 2007 – Jan 2017



8-6 4dSU13 – BRIGHTON

8-6-1 MANAGEMENT SUMMARY

TABLE 8-6 A SUMMARY OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE BRIGHTON FRONTAGE (SURVEY UNIT 4DSU13)

DEFENCE SECTION	OPERATOR	SMP POLICY	CURRENT SOP (ALLOWABLE OT*) AND DEFENCE TYPE	SEDIMENT BUDGET ANNUAL LOSSES IN M³)⁺	RECOMMENDED MANAGEMENT	PLANT ACCESS AND ENVIRONMENTAL RESTRICTIONS
A	BRIGHTON AND HOVE CITY COUNCIL	HTL	>1:200 (10) GROYNED BEACH	-92 (-1,673 TO 1,490)	MONITOR BEACH CSA	PLANT AND VEHICLE ACCESS
B			>1:200 (10) VERTICAL SEAWALL	-184 (-3,346 TO 2,981)	MONITOR BEACH CSA	VEHICLE ACCESS
C			>1:200 (10) VERTICAL SEAWALL WITH STEPPED REVETMENT	-184 (-3,346 TO 2,981)	MONITOR BEACH CSA	VEHICLE ACCESS
D			>1:200 (10) GROYNED BEACH	-1,139 (-13,837 TO 6474)	MONITOR BEACH CSA	GATED PLANT AND VEHICLE ACCESS
E			>1:200 (10) VERTICAL SEAWALL	-1,139 (-13,837 TO 6,474)	MONITOR BEACH CSA	VEHICLE ACCESS
F			>1:200 (10) VERTICAL SEAWALL	263 (-3,000 TO 3,844)	MONITOR BEACH CSA	VEHICLE ACCESS
G			>1:200 (10) CONCRETE VERTICAL SEAWALL	132 (-1,500 TO 1,922)	MONITOR BEACH CSA	VEHICLE ACCESS
H			>1:200 (10) VERTICAL SEAWALL	-131 (-8,870 TO 12,306)	MONITOR BEACH CSA	VEHICLE ACCESS
I			>1:200 (10) PROMENADE WITH VARIOUS WALLS	-395 (-6,539 TO 3,467)	MONITOR BEACH CSA	PLANT AND VEHICLE ACCESS
J			>1:200 (10) PROMENADE WITH VARIOUS WALLS	-395 (-6,539 TO 3,467)	MONITOR BEACH CSA	
K			>1:200 (10) PROMENADE	1,703 (-2,280 TO 6,366)	MONITOR BEACH CSA	
L			>1:200 (10) PROMENADE WITH VARIOUS WALLS	1,703 (-2,280 TO 6,366)	MONITOR BEACH CSA	
M			>1:200 (10) CONCRETE PROMENADE	-32 (-4,178 TO 14,177)	MONITOR BEACH CSA	PLANT ACCESS WITH RAMP

N			>1:200 (10) CONCRETE PROMENADE	512 (-8,532 TO 6,801)	MONITOR BEACH CSA	PLANT ACCESS WITH RAMP
O			>1:200 (10) BRICK WALL	1,910 (-2,694 TO 5,740)	MONITOR BEACH CSA	
P			>1:200 (10) CONCRETE WALL	1,910 (-2,694 TO 5,740)	MONITOR BEACH CSA	
Q			>1:200 (10) BRICK WALL	1,910 (-2,694 TO 5,740)	MONITOR BEACH CSA	PLANT ACCESS WITH RAMP
R			>1:200 (10) CONCRETE PROMENADE	3,080 (-1,366 TO 13,152)	MONITOR BEACH CSA	
S			>1:200 (10) CONCRETE SEAWALL WITH RETURN	3,080 (-1,366 TO 13,152)	MONITOR BEACH CSA	
T			>1:200 (10) VERTICAL SEAWALL	1,540 (-683 TO 6,576)	MONITOR BEACH CSA	
U			>1:200 (10) CONCRETE SEAWALL	1,540 (-683 TO 6,576)	MONITOR BEACH CSA	

* The minimum CSA (m^2) before undermining occurs (bold)
** Allowable overtopping is measured in l/m/s and determines the SoP
+Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

8-6-2 MANAGEMENT HOTSPOTS

Brighton is gaining material annually and the west to east sediment transport means that this material builds up around the Brighton Marina. The majority of the profiles within the unit are above design especially at the eastern end of the unit. This area could be used to source material for the Southwick recycling as it is within the same sediment cell.

8-6-3 RECOMMENDED FUTURE WORKS

Consider recycling material from the west of Brighton Marina to Southwick erosive area.

Continued monitoring as part of the RCMP.

8-6-4 EMERGENCY WORKS

In an emergency material may be redistributed from the groyne bays which are above design.

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FIGURE 8-6 SUMMARY OF SEDIMENT BUDGET TRANSPORT RATES, ENVIRONMENTAL RESTRICTIONS AND RECOMMENDED MANAGEMENT ALONG THE BRIGHTON FRONTAGE

Polygons: Annual Average Natural Change

- < -10 000 m3 / year
- -5 000 to -10 000 m3 / year
- -1 000 to -5 000 m3 / year
- -1 000 to 1 000 m3 / year
- 1 000 - 5 000 m3 / year
- > 5 000 m3 / year

Environmental Constraints

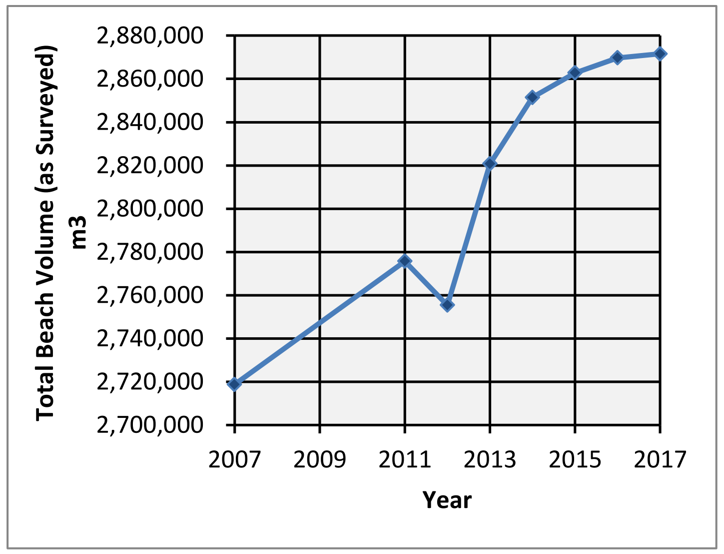
- National or International Designation
- Vegetated Shingle - Restrictions on use of Plant

Floodplain Map

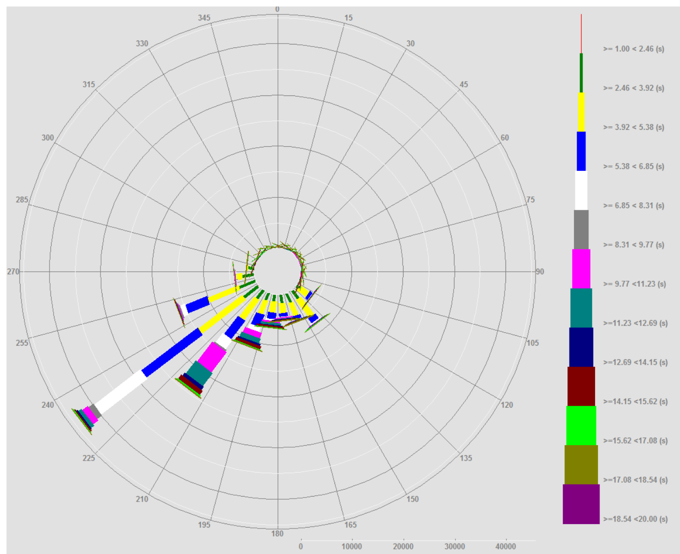
- 1:200 year extreme still water level planar flood map

Map Scale 1: 16,000

Total Volume of Beach Material in Brighton Unit (2007-2017)



Wave Rose for Seaford showing direction, frequency & magnitude of waves Jan 2007 – Jan 2017



8-7 REGIONAL OVERVIEW

TABLE 8-7 A REGIONAL OVERVIEW OF DEFENCES, STANDARD OF PROTECTION, LONGSHORE DRIFT AND RECOMMENDED MANAGEMENT ALONG THE LITTLEHAMPTON TO BRIGHTON MARINA FRONTAGE (SURVEY UNITS 4DSU24 – 4DSU17).

UNIT	SMP SHORT TERM POLICY	CURRENT SOP	SEDIMENT BUDGET ANNUAL CHANGE (M^3)*	MANAGEMENT	RESTRICTIONS
LITTLEHAMPTON TO RUSTINGTON	HTL	>1:200	969	MONITOR BEACH CSA	
RUSTINGTON TO FERRING	HTL	>1:50 <1:100 TO >1:200	18,536	MONITOR BEACH CSA	
WORTHING	HTL	>1:50 <1:100 TO >1:200	7,669	MONITOR BEACH CSA	
LANCING	HTL	>1:200	-10,668	MONITOR BEACH CSA	MATERIAL EXTRACTION RESTRICTED TO BELOW VEGETATED SHINGLE AREA
SOUTHWICK	HTL	<1:1 TO>1:200	-14,595	MONITOR BEACH CSA	
BRIGHTON AND HOVE	HTL	>1:200	10,457	MONITOR BEACH CSA	

* Sediment budget figures show annual average natural change, with the highest positive and negative changes in brackets.

The study area is made up of two separate sediment cells, split by the River Adur. Beach management works should take this into account. As the cells are closed, i.e. material is not naturally exchanged between them, moving material from one into the other will eventually lead to the depletion of the one providing the material. By only recycling material within the same cell, this problem is avoided.

Currently material is transported from Lancing and into Southwick. In the future it would be beneficial to investigate recycling material from Brighton to Southwick and use the build-up of material within Lancing to the west of the Harbour Arm. Considering the construction of a rock revetment at Southwick would potentially reduce the need for such high recycling volumes.

The areas which require close monitoring are:

- The bandstand at Worthing;
- The erosive section at Lancing;
- The accretive section at Lancing;
- Southwick Sections C, D and L;
- Brighton accretive section.

9 MONITORING

Future monitoring is imperative to ensure all aspects of the coastline are maintained and recorded using a controlled method which meets the minimum requirements for individual beaches along the Littlehampton to Brighton Marina stretch.

The three main sources include the Regional Coastal Monitoring Programme (RCMP), which is a national project dedicated to collecting topographic, bathymetric, hydrological and photogrammetry data along the English coastline. For the Littlehampton to Brighton Marina coast, the project has just completed its third Phase (2012-2017) and set to continue into its fourth Phase (2017 to 2021). All data is freely available from www.coastalmonitoring.org. The Environment Agency run Lidar flights, formerly available via Geomatics, are now freely available through Opening Up Government (OGL) www.data.gov.uk and through www.coastalmonitoring.org. Lastly, asset surveys, recycling and replenishment logs, photographic evidence of storms and storm damage are available through the Local Authorities.

9-1 TOPOGRAPHIC SURVEYS

9-1-1 BEACH SURVEYS

Regular beach surveys are extremely useful for providing historic trends, assessing future behaviour and recording the effect of storms or replenishment campaigns on the beach level. Beach levels are monitored against Design, Maintenance and Critical Levels which ensure the beach remains above a level which could cause damage to infrastructure or the public. Regular monitoring of beach levels allows deterioration of the beach to be noted early so pre-emptive works can be undertaken, opposed to remedial works after a failure. Beach levels are used for planning coastal maintenance or larger schemes and monitoring recycling and replenishment volumes.

Beach levels can be acquired through beach profiles, collected using a rover on a detail pole at a known elevation and measuring beach elevations along a known transect on the beach). Beach levels can also be acquired through continuous surveys, conducted either on foot or using an ATV. The GNSS kit is mounted onto a backpack or the ATV and shore parallel lines are walked/driven to collect elevation data along each crest and trough to create a 3D model of the beach.

Profiles are to be spaced at regular intervals, to be determined by the presence of a groyne field, change in orientation and risk – classified by the hinterland (flood basin, soft cliff and dense urban areas). Profiles are referred to as intermediate and designated. Designated profiles are the key profiles which can provide a general oversight to the beach condition, spaced at 200-500m intervals. Intermediate profiles allow full coverage of the beach once per year and are much more closely spaced, between 30-100m apart.

The RCMP has surveyed the beaches along this stretch of coastline since 2003 and has set profiles according to the orientation, risk and groyne fields. From spring 2017 data will be collected along this frontage twice per year, spring and autumn. The survey requirements of the individual locations are listed in Table 9-1.

TABLE 9-1 FUTURE SURVEY REQUIREMENTS 2017-2021

LOCATION	RISK	SEVERITY	SURVEY REQUIREMENTS
RUSTINGTON	LARGE SETTLEMENT IN FLOOD PLAINS	DAMAGE TO PROPERTY, INFRASTRUCTURE AND HARBOUR	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY
FERRING	LARGE PRIVATE SETTLEMENT	DAMAGE TO PROPERTY AND SERVICES	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY
WORTHING	DENSELY POPULATED LARGE SETTLEMENT	SEVERE DAMAGE TO PROPERTY, SERVICES, HUMAN LIFE AND INFRASTRUCTURE	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY
LANCING	LARGE SETTLEMENT	DAMAGE TO PROPERTY AND SERVICES	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY
SOUTHWICK	LARGE SETTLEMENT AND OPERATING HARBOUR. ALSO IMPORTANT RIVER OUTLET	DAMAGE TO PROPERTY, INFRASTRUCTURE AND HARBOUR	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY
BRIGHTON AND HOVE	DENSELY POPULATED LARGE SETTLEMENT	SEVERE DAMAGE TO PROPERTY, SERVICES, HUMAN LIFE AND INFRASTRUCTURE	▪ ONE FULL BMP SURVEY (PROFILES AND 3D MODEL) IN THE SPRING, ONE ADDITIONAL PROFILE SURVEY IN THE AUTUMN* ▪ PROVISION FOR POST STORMS ▪ LIDAR SURVEY BI-ANNUALLY

* This is a minimum requirement. The surveys in this area are currently done by laser scan and so a full 3d model is produced each survey.

9-1-2 POST STORM SURVEYS

In the event of a storm, additional profiles are surveyed to provide an instant overview of any damage; allowing comparison of post storm levels to the design, maintenance and critical levels and should be used to inform any remedial works.

To instigate a post storm survey, a member of the RCMP will contact the Operating Authority (OA) within 12 hours of the storm for guidance on the post storm requirements. If beach is drawn down and it is thought to recover within a few tidal cycles then it is for the OA to decide if a survey will be beneficial. If the beach has been severely eroded and remedial works are imminent, a post storm survey is required immediately. If you have not heard from the RCMP, contact them immediately as they can mobilise for the next low tide.

A post storm survey will collect the data most useful to the OA. If damage has occurred along the whole frontage, a selection of designated profiles will provide an overview. Or, if the damage is more localised the OA should request a survey in a specific area. The RCMP will then survey a feasible number of profiles during a tidal cycle.

It is advised that a post storm survey is undertaken to recalculate the standard of protection provided by the beach using the overtopping charts.

9-1-3 BEACH MANAGEMENT SURVEYS

When beach management works are to be undertaken it might be useful to carry out a pre works (IN) and/or a post works (OUT) survey. Requests should be made to the RCMP as soon as the timing of the works are known to potentially tie at least one of these extra surveys into the regular survey schedule. This might allow a better quantification of sediment volumes added or moved. Similar to the post storm survey, it is carried out to the preference of the OA; as either a general coverage of the beach through designated profiles, a concentrated selection of profiles on a shorter frontage or a full laser scan of the beach. These surveys are likely to have to be funded from maintenance or project specific sources other than the RCMP. There is also a need to fill out a maintenance log when beach management works have been undertaken (see Section 9-8-7).

9-2 BATHYMETRIC SURVEYS

The seabed requires surveying as the cross shore transport of sediment is rarely captured in the laser scans. Ideally, one bathymetric survey per year would provide a clearer indication to the seabed movements but due to the financial implications of each bathymetric survey it is not feasible to commission them regularly. With this is mind, a full multi-beam survey was undertaken in 2013 which captured the whole coastline from Littlehampton to Brighton Marina in a 3D model, recording the substrate and elevation. To reduce the cost of future surveys the chalk or rock platform could be disregarded for the foreseeable future as it would not change to allow funding for areas of fine substrate.

9-3 AERIAL SURVEYS

9-3-1 LIDAR

For sections of coastline which are difficult to access or have soft cliffs, Lidar is a suitable method of data collection for monitoring. Lidar data will be collected along this whole stretch of coastline biannually as part of the RCMP in Phase IV.

9-3-2 ORTHORECTIFIED PHOTOGRAPHS

Ortho-rectified photographs provide a visual comparison of the coastline and allow GIS data to be overlaid onto the most updated photographs. As the coastline is continuously changing it would be recommended to update the photographs every three to five years.

9-3-3 Unmanned Aerial Vehicle (UAV)

The UAV is a piece of quickly evolving technology which can be used to produce photogrammetry of the beach from the air; similar to Lidar. A control network would need installing to provide control points for the UAV to survey to ensure the data was accurate.

9-4 ASSET MONITORING

9-4-1 FULL INSPECTION

In accordance with the Flood and Water Management Act (2010) OAs are required to maintain a record of flood and coastal defence assets, and it is recommended that this record is updated annually with the condition of these assets.

Each asset should be recorded with the location, defects, recommended repair works and a time frame for completion. All assets should be photographed and compared against previous asset surveys to monitor any deterioration.

Seawalls should be assessed in terms of parapet or capping beam, wall section and wall toe against spalling, cracking, holes, missing or damaged sealant, slippage of precast concrete blocks, sinking, slumping of concrete revetment, vegetation growth, exposed rebar.

In addition, groynes (timber and rock) should be assessed for missing or burnt planks, eroding piles, conditions of landward connection, seaward roundhead, groyne capping beam, sheet piling; or rock groynes, slippage or holes.

9-4-2 VISUAL INSPECTION

In addition to the full asset survey it is recommended that the OA carry out a visual inspection of their coastline once per month between October and March to check for damage to the frontage caused by persistent wave attack. Waves can reduce the crest width without exceeding the storm threshold, and if the wave direction is persistently from the same direction then large volumes of sediment can be transported along the coastline leaving weak areas exposed. Any damaged sections should be photographed and dated.

Following a storm, additional visual inspections are recommended to monitor damage until remedial works can be undertaken. Again, photographs should be taken and logged with the location and date of the storm as this can verify future overtopping calculations.

A full visual inspection is recommended in the spring each year to assess any damage from the winter period and allow sufficient time to organise remedial works in preparation for the following winter. This visual inspection could be combined with the full asset survey or performed as a separate check.

9-5 ENVIRONMENTAL SURVEYS

Construction work within the coastal zone can be disruptive to the plant life. However with a good understanding on the location and distribution of vegetation works can be planned to avoid any damage. A site visit and/or use of recent, high resolution aerial photography, such as that produced by the RCMP, should be used to identify the need for a vegetation survey.

If a site is identified as sustaining a significant community of shingle vegetation then monitoring should be carried out pre and post works. A suitable method is described within Appendix A of the East Sussex Vegetated Shingle Management Plan (Smith, 2009). It is preferable to undertake the surveys between June and August.

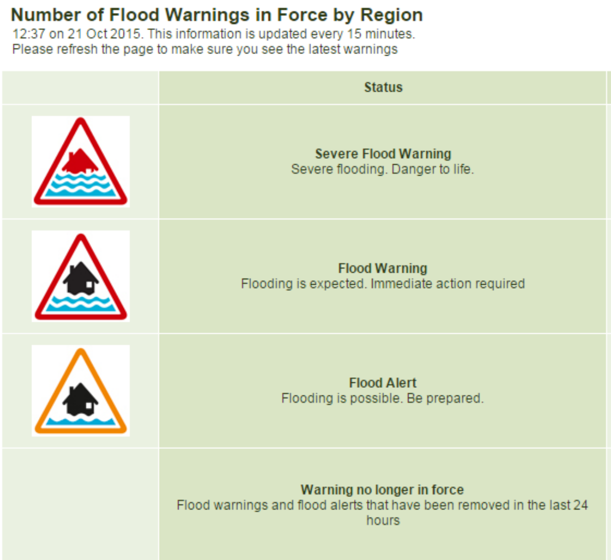
9-6 HYDROLOGICAL MONITORING

Wave and weather data is required along this coastline. The RCMP has several buoys placed around the coast. This data supports the beach monitoring but more importantly records the wave heights which informs the OA if the waves have exceeded the storm thresholds. Data are freely available from www.channelcoast.org.

Tide gauges are also placed around the coast with the nearest to this frontage placed at Dover and Herne Bay. The Met Office provides detailed weather and marine conditions for several areas around the coast.

9-7 WARNING PROCEDURES

It is a requirement for Lead Local Flood Authorities (LLFA) to have flood warning systems in place. It is recommended that the Environment Agency's Flood Warning System is used to inform the engineers or on-call staff of any imminent or predicted flood warnings (Figure 9-1). Email and text alerts can be set up for all involved staff. It is also recommended to monitor the wave buoys before, during and after a storm; text alerts for waves exceeding the storm threshold at individual wave buoys can also be set up at channelcoast.org/alerts.


Number of Flood Warnings in Force by Region
12:37 on 21 Oct 2015. This information is updated every 15 minutes.
Please refresh the page to make sure you see the latest warnings

	Status
	Severe Flood Warning Severe flooding. Danger to life.
	Flood Warning Flooding is expected. Immediate action required
	Flood Alert Flooding is possible. Be prepared.
	Warning no longer in force Flood warnings and flood alerts that have been removed in the last 24 hours

FIGURE 9-1 ENVIRONMENT AGENCY FLOOD WARNING CATEGORIES WWW.ENVIRONMENT-AGENCY.GOV.UK

9-8 REPORTING AND INTERPRETATION

9-8-1 ANNUAL BEACH REPORT

The Operating Authority (OA) can expect an annual beach report detailing the wave conditions, recycling works and the results of the topographic survey indicating the beach response throughout the year which will be issued by the RCMP. This report will highlight areas of concern and any repeatedly eroding or accreting sections as well as suggesting areas to monitor during the next year.

The CSA of the beach will be plotted on a graph to compare the most recent survey to the design, maintenance and critical levels as described in Chapter 7. The most recent CSA will also be plotted onto a series of overtopping graphs to illustrate the risk of overtopping along the frontage (Appendix G).

9-8-2 POST STORM REPORT

Following a post storm survey a short analysis report will be sent to the OA to identify the effect of the storm compared to the pre storm condition. It will highlight any areas of coast that have become vulnerable by plotting the latest CSA against the design, maintenance and critical levels. This report will be sent out by the RCMP.

9-8-3 PRE AND POST WORK REPORT

If a survey was requested before the maintenance or scheme works this will be compared to the post works survey to determine the total volume of sediment transported. The two surveys will be analysed further in the annual report to monitor how the works have responded to the wave climate. This report will be sent out by the RCMP.

9-8-4 WAVE REPORT

A report for each wave buoy is issued once per year, by the Channel Coastal Observatory, to summarize the significant wave heights and any events what exceed the storm threshold. The wave buoys currently in action are located at Rustington and Seaford.

9-8-5 SANDS

After each survey the topographic and Lidar data is uploaded to SANDS and sent to all OA after all surveys in their database are complete. The survey units covered by this report (4dSU18 Rustington, 4dSU17 Ferring, 4dSU16 Worthing, 4dSU15 Lancing, 4dSU14 Southwick and 4dSU13 Brighton and Hove) are within the SDCG database.

9-8-6 ASSET REPORTS

In the event of a storm, it is advised that the OA survey the assets along their stretch of coast and report any large defects such as seawall collapse or groyne failure to Canterbury City Council with a photograph, exact location and accompanying text, to allow a recalculation of the standard of protection.

9-8-7 MAINTENANCE LOGS

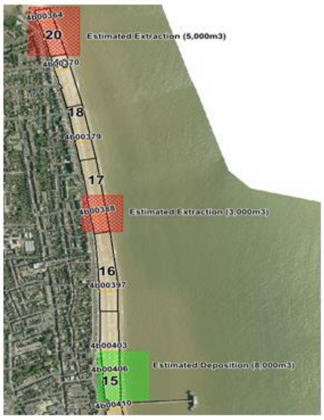
It is important that all beach management works (recycling, beach recharge, reprofiling) should be logged on the appropriate form to indicate the extraction and deposition locations, the quantities moved and the start and end date of the activity (Figure 9-2).

Maintaining these records allows differentiation between artificial beach movement and natural beach transport. These volumes feed into the shingle sediment budget (Appendix E) and the annual reports released by the RCMP. Re-profiled beaches require a log to indicate the location; no further information is required.

It is the responsibility of the OA to issue the maintenance log within one month of completion of the works and sent to the RCMP based at Worthing Borough Council. A blank maintenance form is attached on the following page, to be completed following each artificial movement of shingle or sand.

Maintenance Log: Deal

☒ Deposition ☒ Extraction ☐ Reprofiling



Date	April 2015	Logged by	Andy Stevens

Description of Works/Notes
8,000m³ recycling at North Deal from Sandown Castle to north of pier. Quantities from Alistair Pitcher, area estimated

Description of Frontage			
Before		After	

Quantify extraction/deposition (Note: If volume unknown conversion used is 1 tonne: 1.8 m³ of material)

Profile/Groyne No.	Profile/Groyne No.	Quantity (m³)		Lorry Capacity (m³)	Number of lorry loads	Material Description (click in cell for drop down)
			Or			
	Total:		m³			

FIGURE 9-2 EXAMPLE OF COMPLETED RECYCLING LOG FOR DEAL (2015)

Maintenance Log: [place name here]

☐Deposition ☐Extraction ☐Reprofiling

Date		**Logged by**	

Description of Works/Notes

Description of Frontage			
Before		**After**	

Quantify extraction/deposition (Note: If volume unknown conversion used is 1 tonne: 1.8 m^3 of material)

Profile/Groyne No. Start	Profile/Groyne No. End	Quantity (m^3)		Lorry Capacity (m^3)	Number of lorry loads	Material Description (click in cell for drop down)
			Or			

Total: m^3

GLOSSARY

Accretion	The addition of sediment vertically or horizontally due to the natural action of waves, currents and wind.
Accumulation	Any addition of sediment, either natural (accretion) or man-made.
Alluvium	A deposit resulting from the action and products of rivers or streams.
Apron	A layer of stone, concrete or other material to protect the toe of the sea wall against scour.
Armour	Resistant rocks or specially shaped concrete blocks of a specific size, geometry and weight which are placed as primary protection against wave action on the seaward side of other structures (see revetment).
Asset	This refers to something of value and may be environmental, economic, social, recreational and so on.
Backshore	A morphological term for the area of beach that lies between high water and the landward limit of marine (storm wave) activity.
Backwash	The seaward return of the water following the up-rush (swash) of the waves. For any given tide stage the point of farthest return seaward of the backwash is known as the Limit of backwash. Depending on the permeability of the beach the water volume in the backwash is smaller than in the swash.
Bar	An elongated deposit of sand, shingle or silt, occurring slightly offshore from the beach and submerged at high tide. The bar may be parallel to the beach or connected and at an angle.
Barrier Beach	A sand or shingle bar above high tide with low lying land or a lagoon on the landward side.
Bathymetry	Topography of the sea floor usually below low water.
Beach	The zone of non-cohesive material (e.g. sand, gravel) that lies between the mean low water line and the place where there is a marked change in material or physiographic form, or to the line of permanent vegetation (the effective limit of storm waves and storm surge). The beach or shore can be divided into the foreshore and the backshore.
Beach crest width	The horizontal distance of the crest measured from the seaward edge of the promenade (or other determined point, see beach) to the point where the beach slope angle drops down towards the sea. This usually assumes a uniform crest level but can also include a gentle slope. A better term is 'beach width at xmOD'.
Beach face	Upper surface of the beach.
Beach Profile	Cross-section (side view) of the beach perpendicular to the shoreline. The profile extends from a point landwards of the backshore to low water or beyond.
Beach recharge	This is the management practice of adding new beach sediment (such as sand or gravel) to a beach using material from outside the sediment cell (for example offshore dredging sites or inland quarries). This is also known as beach

replenishment or beach (re)nourishment.

Beach recycling The movement of sediment along a beach, typically from areas of accretion to areas of erosion.

Beach re-profiling The shaping of the beach profile to achieve a desired crest height, width or slope, typically using bulldozers or other plant.

Berm A constructive ridge located along the higher part of a beach, above high water as a result of cross shore transport moving sediment towards the swash limit. It is marked by a break of slope at the seaward edge. There are usually a sequence of berms present with storm berms located in the back beach area.

BMP Beach Management Plan. It provides a basis for the management of a beach for coastal defence purposes, taking into account coastal processes and the other uses of the beach.

Brackish water Freshwater mixed with seawater.

Breach Failure of a barrier beach or coastal protection structure allowing flooding through tidal water exchange for at least half of the tidal cycle, i.e. the level of the breach is at or below 0mOD.

Breaching Process of removing or lowering a beach or structure to form a breach.

Breaker zone Area in the sea where the waves break.

Breakwater A protective structure of stone or concrete used to break the force of waves, reducing wave energy and hence enhancing protection to the shore.

CCO Channel Coastal Observatory. Based at the National Oceanography Centre in Southampton, responsible for the distribution of data collected under the six Regional Coastal Monitoring Programmes.

CD Chart Datum – an arbitrary local datum or plane to which depths or heights are referred. (Also see OD).

Cliffing Cliffing on beaches refers to the development of seaward slopes in beach material that are at the angle of repose (Depending on the beach material properties [grain size composition, moisture, compaction, cementation] the angle of repose can vary between ~35 and 90 degrees.), usually with a sharp break of slope to the beach below developing near the wave run-up limit.

Climate Change Long term changes in climate. The impact of climate change along the coast is usually associated with changes in sea level and wave climate.

Coastal defence General term used to encompass both coast protection against erosion and sea defence against flooding.

Coastal processes Collective term covering the action of natural forces on the shoreline and nearshore seabed.

Coastline The generalised shape, outline, or boundary of a coast, which marks the area between the seaward limit of terrestrial influence and the landward limit of marine influence.

Consequence	An outcome or impact such as economic, social or environmental impact. It may be expressed quantitatively (e.g. monetary value), categorically (e.g. high, medium, low) or descriptively.
Crest	Highest part in cross section of a beach or structure (e.g. breakwater or sea wall)
Crest level	The height of the crest (usually the highest point), generally in mOD.
Deep water	Area where surface waves are not influenced by the sea-bed, i.e. where water depth exceeds half the wavelength.
Defence	Manmade structure (e.g. sea wall, embankment, recharged beach) or natural feature (e.g. beach, dune) that prevents seawater from reaching the hinterland under varying conditions.
DEFRA	Department for Environment, Food and Rural Affairs, formerly the Ministry of Agriculture, Fisheries and Food (MAFF).
Delta	Sediment body, which is formed where a sediment-laden current enters an open body of water, and deposits its sediment load as a result of a reduction in velocity of the current.
Depth limited (waves)	Situation in which wave propagation is limited by water depth.
Downdrift	Direction of longshore movement of beach materials.
Dredging	Excavation, digging, scraping, drag lining, suction dredging to remove sand, silt, rock or other underwater sea-bed material.
Drift reversal	A switch of an indigenous direction of littoral transport.
Drift-aligned	A coastline that is orientated obliquely to prevailing incident wave fronts. The coast is characterised by strong longshore transport.
Dune	A landform produced by the action of wind on unconsolidated material, normally sand, to produce ridges or mounds of loose sediment.
Dynamic equilibrium	A state of balance between environmental conditions acting on a landscape and the resisting earth material which themselves fluctuate around an average that is itself gradually changing.
Embankment	A linear mound of earth that stretches some distance along the coast that protects the hinterland behind from flooding.
Environment Agency (EA)	UK non-departmental government body responsible for delivering integrated environmental management including flood defence, water resources, water quality and pollution control. It has the strategic overview of all flood and coastal erosion risk management.
Environmental Impact Assessment	Environmental Impact Assessment. Detailed studies that predict the effects of a development project on the environment. They also provide plans

(EIA)	for mitigation of any significant adverse impacts.
Erosion	The removal of any material (clay, rock, soil, sand, gravel) by such agents as running water, waves, wind, moving ice and gravitational creep or falls from its original location. The landward retreat of a shoreline due to these processes.
Estuary	Mouth of a river, where fresh river water mixes with the seawater.
Flint	Micro-crystalline nodules or bands of silica found in the chalk. It is dark grey or black when recently released from the chalk or brownish in colour when it has been removed from the chalk for tens of thousands of years.
Flooding	Refers to inundation by water of land whether this is caused by breaches, overtopping of banks or defences, or by inadequate or slow drainage of rainfall or underlying ground water levels due to tide locking of the coastal outfall structures.
Foreshore	A morphological term for the lower shore zone/area on the beach that lies between mean low and high water.
Geographic Information System (GIS)	Software which allows the spatial display and interrogation of geographic information such as ordnance survey mapping and aerial photography.
Groundwater	The zone in a soil or rock that is saturated with water, mostly derived from surface sources.
Groyne	A structure, which is generally built approximately perpendicular to the shoreline in order to control the movement of beach material and reduce longshore currents and/or to trap and retain beach material. Most groynes are made of timber, rock or concrete and extend from a sea wall or the backshore wall onto the foreshore and rarely even further offshore. They can also take the form of T-shaped groynes, fish-tail and terminal groynes. Other structures perpendicular to the coastline (e.g. outfalls, ramps) can function as a groyne.
Groyne bay	The bay between two groynes.
Groyne field	Series of groynes acting together to protect a section of beach.
Hazard	A situation with the potential to result in harm. A hazard does not necessarily lead to harm.
Hinterland	The land directly adjacent to and inland from a coast, extending landward from the upper limit of extreme wave and tidal energy.
Hold the Line (HTL)	Shoreline Management Plan policy to hold the existing defence line by maintaining or changing the standard of protection. This policy should cover those situations where work or operations are carried out in front of the existing defences (such as beach recharge (see the glossary), rebuilding the toe of a structure, building offshore breakwaters and so on) to improve or maintain the standard of protection provided by the existing defence line.
H_s	See significant wave height.
Hydrodynamic	The process and science associated with the flow and motion in water.

Intertidal areas	The area between mean high water level and mean low water level in a coastal region.
Inundation	An overflow of water or an expanse of water submerging land.
Joint Probability	The probability of two (or more) variables occurring together.
Joint Return Period	Average period of time between occurrences of a given joint probability event.
Land Reclamation	Process of creating new, dry land on the seabed.
Landslides	The large-scale mass movement of sub-aerial material down-slope, or its vertical movement down a cliff face.
Longshore drift/ transport	Transport of sediment along the shore by the combined effect of swash and backwash set up by wave driven currents. Currents produced in the surf zone are caused by waves breaking at an angle and the current running roughly parallel with the shore. (Also see drift-aligned, drift convergence, drift divergence, drift reversal).
Long term	Refers to a time period of decades to centuries.
Managed Realignment (MR)	Shoreline Management Plan policy to realign the shoreline by allowing the shoreline to move backwards or forwards, with management to control or limit movement (such as reducing erosion or building new defences on the landward side of the original defences).
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water Spring (MLWN)	The lowest level to which neap tides retreat on average over a period of time (often 19 years).
Mean Low Water Spring (MLWS)	The lowest level to which spring tides retreat on average over a period of time (often 19 years).
Mean Sea Level (MSL)	Average height of the sea surface.
Medium term	Refers to a time period of decades.
Met Office	UK Meteorological Office.
Metres Ordnance Datum (±mOD)	Elevation in metres above or below Ordnance Datum.
Natural Processes	Those processes over which people have no significant control (such as wind and waves).

Nearshore	The zone, which extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20m.
No Active Intervention (NAI)	Shoreline Management Plan policy where there is no investment in coastal defences or operations. This assumes that existing defences are no longer maintained and will fail over time or undefended frontages will be allowed to evolve naturally.
Offshore	The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the seabed on wave action is small in comparison with the effect of wind.
Offshore Bank	A large scale unconsolidated body of soft sediment, such as sand, gravel and mud which can form topographic highs on the seabed. They are located in the offshore zone and are permanently covered by shallow sea water, typically at depths of less than 20 m below chart datum.
Operating Authority	A body with statutory powers to undertake flood defence or coast protection activities, usually the Environment Agency or maritime District Council.
Ordnance Datum (Newlyn)	A universal zero point/datum used in the UK, equal to the mean sea level at Newlyn in Cornwall.
Overtopping	Water carried over the top of a coastal defence due to wave run-up or still water level exceeding the crest height. See 'green water', 'white water' and 'overwashing'.
Overwashing	Overtopping that leads to water and sediment transported landward which does not return back to the sea following the event.
Percolation	The process by which water flows through the interstices of sediment. Specifically, the infiltration of water during swash into the unsaturated beach material which reduces wave run-up on the beach but which can also lead to water seepage at the landward side, potentially causing instability of the landward slope or a barrier.
Pile	Long heavy section of timber, concrete or metal, driven into the ground or seabed as support for another structure. Especially around/or at the toe of a shore protection structure.
Recession	Movement of the shoreline to landward.
Reef	A ridge of rock or other material lying just beneath the surface of the sea.
Regression	A fall in sea-level resulting in withdraw of the sea from the land.
Relict	Geomorphological feature formed or sediment deposited under past processes and climatic regimes.
Return Period	A statistical measure denoting the average probability of occurrence of a given event over time.
Revetment	A sloping surface of armour used to protect an embankment, sea wall or natural shoreline against erosion.

Rock platform	Gently seaward sloping, intertidal bench cut into the land mass by the action of waves and also known as a wave-cut platform.
Roll back	The gradual net landward migration of the coastline, includes rollover of a subaerial sediment barrier, mainly shingle and gravel.
Saltmarsh	An area of soft, wet land periodically flooded by saline water. Usually characterised by grasses and other low vegetation. Also known as a salting.
Scour	Permanent or temporary erosion of underwater material by waves or currents, especially at the interface between sediment and a structure.
Sea wall	A shoreline structure primarily designed to prevent flooding, erosion and other damage due to wave action. Structure types include solid, near vertical steel of concrete structures of different profiles. A stronger deviation from the vertical indicates a 'revetment'.
Sediment	Particles of rock covering a size range from clay to boulders.
Sediment cell	A length of coastline and its associated near shore area within which the movement of coarse sediment (sand and shingle) is largely self-contained. Interruptions to the movement of sand and shingle within one cell should not affect beaches in an adjacent sediment cell.
Sediment sub-cell	A smaller part of a sediment cell within which the movement of coarse sediment (sand and shingle) is relatively self-contained.
Sediment supply	The source of sediment.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents, waves or wind.
Setback	Prescribed distance landward of a coastal feature (e.g. the line of existing defences).
Shingle	Gravel-sized beach material, normally well rounded as a result of abrasion.
Shoreline	A boundary line between land and water.
Shoreline Management Plan (SMP)	A non-statutory plan, which provides a large-scale assessment of the risks associated with coastal processes and presents a policy framework to reduce these risks to people and the developed, historic and natural environment in a sustainable manner. The first SMP (SMP1) was completed for the Isle of Wight in 1997. The SMP is periodically reviewed. The second SMP (SMP2) is being competed in 2010.
Short term	Refers to a time period of months to years.
Significant wave Height (Hs)	The average height of the highest of one third of the waves in a given sea state.
Sink	Area at which beach material is irretrievably lost from a coastal cell, such as an estuary, a deep channel in the seabed or dunes inland.

Spit	An elongated accumulation of sand or gravel, which projects into the sea or across a tidal inlet. Longshore drift of material is usually responsible for the development of a spit.
Standard of Protection (SoP)	The level of return period event which the defence is expected to withstand without experiencing significant failure.
Still Water Level (SWL)	Average water surface elevation at any instant, excluding local variation due to waves and wave set-up, but including the effects of tides and surges.
Storm Surge	A rise in water level in the open coast due to the action of wind stress as well as a change in atmospheric pressure on the sea surface. A surge typically has a duration of a few hours. See 'surge'
Subtidal	Part of the coast that is permanently below water.
Surge	Changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative.
Suspended Sediment	A mode of sediment transport in which the particles are supported, and carried along by the fluid. See 'bedload transport'.
Swell Waves	Remotely generated wind-waves (i.e. Waves that are generated away from the site). Swell characteristically exhibits a more regular and longer period and has longer crests than locally generated waves.
Tidal range	Difference in height between high and low water levels at a point.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of primarily the moon and sun acting on the rotating earth.
Toe level	The level of the lowest part of a structure, generally forming the transition to the underlying ground.
Tombolo	An accumulation of sediment from the shore to an offshore island, formed by the deposition of material when waves are refracted and diffracted around the island. In a tidal environment a tombolo may exists at all states of the tide or only during lower states leaving a 'salient' at high tide.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Trigger Levels	A set of criteria that trigger an intervention. The intervention can range from increased monitoring to preparation of interventions to an intervention. There is a sequence of Trigger Levels with an increasing level of action and associated costs.
Undermining	Erosion at the base, e.g. of a sea wall, so that the feature above becomes unstable and is vulnerable to collapse. Usually the consequence of 'scour'.

Updrift	Direction opposite to the predominant movement of longshore transport.
Wave Climate	The seasonable or annual distribution of wave height, period and direction measured over a longer period of time.
Wave Direction	Direction from which a wave approaches.
Wave Height	The vertical distance between the crest and the trough.
Wave Hindcast	The retrospective forecasting of waves using measured wind information.
Wave Period	The time it takes for two successive crests (or troughs) to pass a given point.
Wave Return Wall	A sea wall whose seaward face is designed to reflect wave energy.

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